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W C Armstrong

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THE RELATION OF RAILROADS AS COMMON CARRIERS TO THE STATE AND FEDERAL GOVERNMENTS

Judge James C. Davis, Des Moines, Iowa.

Presented November 15, 1911.

I understand that you have a practice, after the presentation of the paper, of discussing it and giving the reader of the paper a chance to reply. I belong to a society in Des Moines known as the Prairie Club. We have a paper once a month, and after the paper is concluded it is discussed and the reader of the paper has a right to reply. We have one additional rule in that club which I am not averse to your adopting tonight, and that is no member of the club is permitted to say anything complimentary of the paper. I want to relieve any gentleman present of any embarrassment if he feels like criticising.

I have no intention of apologizing for this paper, but I am going to make one word of explanation. When I was honored by an invitation last August to appear before you, and the subject was suggested to me on which I might prepare a paper, I thought it was such a long time until November or December that I should have ample opportunity to prepare the sort of paper that I desired. I have procrastinated, and I want to say to you at the start that the paper is a disappointment to me. It will at least have the merit of reasonable brevity.

In my relations with the railroad I have become very much concerned in a few topics, some of them from a modern point of view. I am wonderfully interested in this question of employers' liability, and how railroads will finally compensate their injured employes. I see such a dreadful waste of money in the present system. I have been much interested in the complicated matter of freight rates and how we will finally arrive at some reasonable and satisfactory conclusion of that question. And then, I have been interested in this large problem of the relation

of the state and federal governments to railroads. In fact, they are sort of hobbies of mine, and you know when a man is invited to talk on a hobby he never can refuse the invitation.

I am reminded of an ancient story, which may illustrate my position as to this subject, of a gentleman who was invited to go through an insane asylum. He went through in the companionship of the superintendent, who remarked: "Now, you will find some intelligent looking fellows that have some mental idiosyncrasy. Don't notice it. Try to encourage them." As he passed along a rather fine looking man rode up on a broomstick and said, "Whoa!" The visitor, in order to carry out his instructions, said, "That is a very fine horse you are riding." The crazy man said: "Why, you damned fool, that isn't a horse; it's a hobby. If it was a horse I could get off."

That is my relation to this subject.

At this time, when there are so many vital economic questions in process of solution, there is no more interesting, far-reaching, and important dispute before the courts and the people of this country than the respective powers of the federal government and the authority of the several states, in the multiplied and complicated relations to the railways of the land.

The Interstate Commerce Commission, claiming and exercising authority over all interstate commerce; the several state commissions, exercising authority over local commerce within their respective states, and the railways, some independent lines operating through fifteen or twenty separate states, and all of them in combination transporting freight and passengers under contracts which contemplate rates and journeys from one extreme of the country to another, present complicated questions of conflicting rights, authority, and jurisdiction that are extremely difficult of any sort of fair and practical solution.

The tremendous and unprecedented growth of the transportation interests of this country, presenting innumerable questions not contemplated by the framers of our constitution, coupled with our dual form of government, whereby two authorities, both supreme in their respective jurisdictions, act at the same time upon one agency operating in a territory regulated by both, must result in many and sometimes serious conflicts.

Local rivalries and competition, as between the several states, induce and encourage the state authorities to make regulations favorable to their particular territory, and necessarily disadvantageous to their neighbors, and the controlling power of the federal government is continuously called upon to keep the commercial intercourse between the states free from local exactions and discriminations, as the Constitution of the United States intended it should be.

A proper appreciation of the magnitude and complexity of the questions presented to the traffic departments of the rail-

roads, the courts, and the lawyers, can only be reached by at least a brief summary of the rapid growth and development of the railway interests of America.

When we consider that there are men still living who can remember when there were practically no railroads in the United States; when we recall that within the memory of these men there were grave discussions in legislative assemblies, and in the public press, as to the relative merits, in the way of speed and reliability, between horses, canal boats and steam railroads, the present perfection of railroad transportation is a splendid tribute to the ingenuity, courage and enterprise of American genius. It is no phrase of poetry or oratory to say that railroads have annihilated distance, overcome mountains, and made travel through barren and desert wastes safe, convenient, luxurious, and enjoyable. It is also a statement of fact, rather than a pleasant vagary of fiction, when we say that the railroads of America have been the most potent element in the general settlement, growth, and prosperity of this country.

The rapid growth of railroad construction led, in that period after the railroads had passed the experimental stage, to much bitter controversy and antagonism as between the general public and the transportation interests.

The commercial interests of the land—and by commercial interests is meant all which produce property for sale or exchange, including the mines and the farms, as well as the strictly mercantile and manufacturing enterprises—must be in accord with the transportation interests. These two great and controlling factors of commercial prosperity—the shipper and the producer on the one side, and the carrier on the other—are absolutely dependent upon each other. When the tonnage producer is prosperous, and has an abundance of freight for carriage, the railroads share in that prosperity. If business languishes, and the shipper has but little to offer in the way of freight, there is a corresponding diminution in the prosperity of the carrying companies, and in the great struggle which for many years has been in progress, the differences between the railroads and the people have not been, in many instances, so much controversies with actual patrons of the roads—men who are contributing to their support and maintenance—but have been differences created and fostered by politicians and political parties.

In considering the growth of railroad interests, the time of such development is ordinarily divided into three periods:

From 1830 to 1850, during which time the construction of railroads was in an experimental stage; practical railroad building in the United States commenced, in a general way, about 1830. During this first period, the general plan of railroad construction, in many instances, was similar to that of the ordinary highway, in which the government was expected to share a large

part of the expense, and, if not the owner, at least to be in control of the operation of the road.

In the second period, from 1850 to 1870, during which time the science of railroading was rapidly developed, the construction, maintenance, and operation of railroads was largely turned over to private enterprise, the various governments, state and national, not attempting to exercise any general or specific control, the belief being that competition between the independent lines of road would obtain for the public all that government control or ownership can ever obtain, namely, reasonable rates and safe and convenient service.

The third period, from about 1870 down to the present time, represents the commencement and the growth of government control. During this period the attitude of the state and federal governments toward railroad corporations was radically altered, in that there was evolved the theory of government control, the state governments claiming the right to exercise control over those local matters which come under the general definition of police power, and also the right to exercise control over the service and charges in the transportation of freight and passengers, when the carriage was confined wholly to points within a specific state or territory. The federal government, at a little later period, claimed and assumed authority to control those larger interests coming under the head of interstate commerce, and also commerce between the United States and foreign countries.

In the light of the present development and perfection of the transportation business, reference to some of the early discussions in regard to the practicability of railroads may not be uninteresting.

It is reported that Robert Fulton, in 1811, ventured this prophecy:

> "The day will come, gentlemen—I may not live to see it, though some of you who are younger will probably—when carriages will be drawn over these mountains by steam engines, at a rate more rapid than that of a stage on the smoothest turnpike."

Mr. Oliver Evans, one of the early experimenters in building steam carriages, in 1813 said:

> "The time will come when people will travel in stages moved by steam engines from one city to another, almost as fast as birds fly, fifteen or twenty miles an hour."

Even after steam carriages upon railroads were in service, some of the roads were operated upon the theory that anyone could use the rails with his own carriage for transportation. In speaking of the policy of the state of Pennsylvania in this matter, a writer on this subject said:

> "After the state of Pennsylvania had solved the first difficulty by excluding horses, and providing locomotives to furnish motive power, all the vehicles or cars used in moving freight or passengers continued to be owned by individuals, firms, or private corporations until the commonwealth disposed of her public works after her railways had been in operation under state management for nearly a quarter of a century."

And, in describing a discussion between two members of the Pennsylvania legislature in early days, the following is recorded:

> "Two gentlemen were sitting opposite me who were members of the legislature from Chester County, one being a senator. The car stopped, and a man spoke to my traveling companions, saying that he hoped they would oppose the bill to authorize the canal commissioners to put locomotives on the road and control the motive power. The senator said that it should never be done with his consent. Thereupon, as the car drove on, I proceeded to argue the matter, but with poor success, the reply being that the people were taxed to make the railroad, and that the farmers along the line should have the right to drive their own horses and cars on the railroads, as they did their wagons on the Lancaster turnpike, to go to market in Philadelphia; and that, if they were not permitted to do it, the railroad would be a nuisance to the people of Lancaster and Chester counties."

These quotations simply illustrate what great developments have occurred in a comparatively short time, and demonstrate how rapidly the various governments have been obliged to formulate statutes and rules of control to keep pace with the march of progress.

As late as 1850, there was not a mile of railroad in Wisconsin, Tennessee, or Florida, and little, if any, construction west of the Mississippi River. Even in 1870, it is said that one-half of the area of the country was still without railways. The first extended railroad, built for steam cars, is said to have been the Charleston & New Hamburg line, in South Carolina. This line was 137 miles long, and for quite a period was the longest railroad in the world.

Comparing the early condition of railroad construction with the present extent of mileage and capital invested, the comparison becomes bewildering. There is now in this country in excess of 240,000 miles of main line track, and, including all tracks, yards, and sidings, there is in excess of 337,000 miles. These companies employ in excess of 1,754,000 persons, and distribute in wages and salaries annual compensation in excess of $1,172,181,000.

The gross earnings of the railroads for the year 1910 repre-

sented an aggregate of more than $2,841,000,000, and the companies have a capitalization in excess of $14,000,000,000, or about $60,000 per mile of operated line.

The rapid growth of railroad construction created a necessity for the existence of new laws, or what may be more accurately termed the application of old principles to new conditions. There was no railroad law seventy-five years ago, for the reason that there was practically no subject to which such laws should apply, but there is an elasticity underlying the principles of the common law, upon which our whole theory of jurisprudence is founded, by which the old and everlasting principles of that law are made applicable to new and original surroundings, as the development of the law in many new branches, such as railroad, telegraph, telephone, and the multiplied uses of electricity, all bear evidence.

The second period, from 1850 to 1870, represents the time when railroad construction and operation became an established science. The development of new country, and the opening of agricultural lands for settlement, created a great demand for the extension of railroads, and the sentiment of the general public was all in favor of the same. The public, in various ways, made liberal donations, and gave generous support to this end. Special powers were granted by the various legislatures to railroad corporations. They were given the power of eminent domain, authorizing the entry and appropriation of such private property as might be necessary for the proper construction and maintenance of the road. Most of the states passed laws authorizing special taxes, which might be voted by counties, townships, and municipalities in aid of railroad construction. There were magnificent donations of public lands to railroads, especially to those that contemplated building to the Pacific Coast.

During this period, while every interest was encouraging the building of railroads, the government made no effort to control the management and operation of the same, but it was believed that the ordinary rules of competition would give the public convenient service for reasonable compensation, and the original investors in these enterprises believed that were making an investment that they could control as any other private institution.

As the carrying companies continued to grow in strength and power, abuses—some of which were actual, some imaginary and exaggerated—arose. There being no laws regulating the charge for carriage, discrimination appeared; favored shippers received rebates that those less favored did not enjoy; one community was discriminated against in favor of another; cities which happened to be the terminus or touched by two railroads would receive competitive rates much lower than those accorded to cities and towns not so fortunately situated; the private inter-

ests of controlling owners in some railroads led to the building up of distributing centers to the disadvantage of less fortunate points which these interests did not care to favor; long hauls on the same lines of road were made cheaper to points of competition than shorter hauls of the same class of commodities to cities where no such competition existed, and out of this situation there arose a great contest which should finally determine the character of railroad corporations; whether or not they were mere private enterprises, or whether these corporations were subject to govenmental control.

The line of dispute was clearly drawn. The railroads, by their officers and managers, contended that they were private corporations; that their franchises, granted by the several states, contained no suggestion as to government control; that each railroad represented a large investment, made as mere private institutions, and constitutional provisions would be violated if they were not permitted to control their property and use it as any other private enterprise. The public, on the other hand, contended that a railroad was nothing more or less than an improved highway; that highways and turnpikes had from time immemorial been constructed and controlled by the government; that, if the government permitted a private individual or corporation to perform this public service, it did not, therefore, lose control over the enterprise while such individual or corporation was performing the same. It was further contended that the great privileges, especially the right of eminent domain, which were granted to corporations of this character, and the large contributions which were made by the public to the construction of railroads, gave the public an interest in and control over this property. Upon this issue a long and bitter contest followed.

The individual states first undertook the specific regulation of common carriers, including public elevators and warehousemen. The states of Wisconsin, Illinois and Iowa were the pioneers in what was then termed radical legislation, and the legislation of these states was the subject of controversy in the state courts, and finally in the Supreme Court of the United States.

The case which authoritatively determined that the government has the right to regulate the charges and tolls of public-service companies was decided by the Supreme Court of the United States in 1876. This case is entitled Munn vs. Illinois (reported 94 U. S., 124). In it the Supreme Court of the United States delivered an elaborate opinion which forever settled in this country the right of the state governments, and, when applied to interstate commerce, the right of the federal government, to control public-service corporations. The case decided was a consolidation of controversies involving the constitutionality of warehouse and commission laws and railroad commission

laws from Illinois, Iowa and Wisconsin. In the course of its opinion, the court said:

> "When one becomes a member of society, he necessarily parts with some rights or privileges which, as an indivdual not affected by his relations to others, he might retain. 'A body poltiic,' as aptly defined in the preamble of the Constitution of Massachusetts, 'is a social compact by which the whole people covenants with each citizen, and each citizen with the whole people, that all shall be governed by certain laws for the common good.'"

In further speaking of the power of the government, the court said:

> "Under these powers the government regulates the conduct of its citizens one towards another, and the manner in which each shall use his own property, when such regulation becomes necessary for the public good. In their exercise it has been customary in England from time immemorial and in this country from its first colonization, to regulate ferries, common carriers, hackmen, bakers, millers, wharfingers, innkeepers, etc., and in so doing to fix a maximum of charge to be made for services rendered, accommodations furnished, and articles sold."

And the court further said:

> "Property does become clothed with a public interest when used in a manner to make it of public consequence, and affect the community at large. When, therefore, one devotes his property to a use in which the public has an interest, he, in effect, grants to the public an interest in that use, and must submit to be controlled by the public for the common good, to the extent of the interest he has thus created. He may withdraw his grant by discontinuing the use; but, so long as he maintains the use, he must submit to the control."

In reviewing instances where the government had exercised this power of control, the court referred to a statute passed in England in the time of the reign of William and Mary, which contained the following preamble:

> "And whereas divers wagoners and other carriers, by combination amongst themselves, have raised the price of carriage of goods in many places to excessive rates, to the great injury of the trade: Be it, therefore, enacted," etc.

And the Act of Parliament then proceeded to regulate the charges which might be made.

This ancient statute illustrates that combinations of carriers to raise the prices is neither a new nor a modern condition.

In a later case (143 U. S., 549) a more specific rule, as applied to railroads, was stated as follows:

"The creation of all highways is a public duty. Railroads are highways. The state may build them. If an individual or corporation does that work, he is pro tanto doing the work of the state. He devotes his property to a public use. The state doing the work fixes the price for the use. It does not lose the right to fix the price, because an individual or corporation voluntarily undertakes to do the work."

The foregoing illustrate the principles upon which the Supreme Court of the United States acted in sustaining the right of the state and federal governments to regulate the conduct and business of common carriers, and, as an essential to this regulation, further decided that all rates fixed by law must be reasonable, and give the carrier fair compensation for the service to be performed, and such fair compensation must be such as will enable the carrier to maintain and operate its line, provide for depreciation and betterments, and pay a reasonable profit upon the capital engaged in the business, and the courts will set aside as unreasonable any regulations that do not so provide, as being in violation of the provisions of our constitution which provide that private property cannot be taken without due compensation.

The power of control having been established, the legislatures of the several states and the Congress of the United States at once set to work in the line of enacting, especially in later days, in much detail, laws regulating railways and creating commissions whose special duty is to supervise and oversee railroad operation within their several jurisdictions.

Conflicting rights between the several states, as among themselves, and conflicting rights as between the state and federal governments, have resulted in innumerable decisions upon this right of control by the many state and federal courts.

As the importance and complexity of our great interstate and local commerce has increased, the number of conflicts have correspondingly multiplied. The creation and growth of new trade and industrial centers has required new adjustments as to rates and service; the building of new railroads has opened up new and independent territory for distribution and sources of supply, and efforts on the part of local state commissions to protect and foster the commerce and industries of particular states, as against interestate competition and the competition of adjoining states, has led to many contentions between the state and federal authorities.

The marked difference in the length of the local and interstate movement of freight invites constant and invidious comparisons on the part of local authorities of the per ton per mile charged locally, on the comparatively short hauls, with the same charge on the long interstate hauls. The fact that many of the principal materials which enter into our largest manufacturing

enterprises, such as iron, steel, lumber, and their products and combinations, are produced in a few widely separated districts; that tropical fruits, such as oranges, lemons, and bananas, now recognized as staple and necessary articles of food, must be carried great distances and sold at low prices, readily indicates that, if our great interstate commerce is to be sustained, it must not be hampered and embarrassed by state interference and regulation, and, if the various state commissions can establish local rates entirely independent of their effect upon interstate commerce, then the commerce among the states would be so reduced in volume that the general prosperity of the country would be seriously affected, and the United States, instead of enjoying the free movement of a great commerce which now reaches throughout the entire extent of our territorial limits, would be divided up into warring factional districts, and free trade among the states would be destroyed, each individual state attempting, through a system of local rates, to protect its own territory.

The importance of a correct solution of these great questions cannot be over-estimated. It involves not only the solvency of the carrying companies, and the continuation of present centers of commerce and distribution, but the continued prosperity of the country at large.

The question of rates and charges is vital to the existence and continued successful maintenance of any commercial enterprise. In the effort to encourage and stimulate local interests, there has been a tendency on the part of state commissions to arbitrarily fix schedules of tariff charges that do not furnish fair remuneration, such charges being often fixed without any sort of detailed information or careful consideration, but in response to public clamor or political pressure.

In many instances, interestate rates are governed by and dependent upon a combination of local rates, this being true for the evident reason that you cannot successfully maintain a through rate that is in excess of a combination of local rates, so that a reduction in local rates results, in most cases, in an automatic reduction of through or interstate rates. This result, if permitted to continue, must necessarily destroy the tariff upon interstate commerce, and the question must be definitely and permanently settled as to which authority is supreme, and, in case of conflict, which rate and ruling shall prevail.

The interstate commerce in most, if not all, of the several states is so much in excess of the local tonnage that there cannot be a comparison as to the importance of the two items of traffic. So pronounced is this difference that in many states the interstate traffic is the controlling factor, while the local traffic might be described as merely incidental.

In some of the recent controversies, where comparative statistics have been submitted, it has been demonstrated that

frequently the local traffic, if charged with any sort of a fair amount of operating expenses, does not pay the expense of operation. For instance, in the state of Iowa, the revenue derived from the movement of local freight is less than 10% of the gross income of the railroads credited to that state.

The right to maintain, without local interference, the schedule of interstate rates, seems to be essential to the continued efficient operation of the large lines of road.

This controversy as to the right to regulate local and interstate commerce is now pending before the Supreme Court of the United States, in an appeal from decisions rendered by the circuit courts of the United States in Missouri, Minnesota, Arkansas, Oklahoma and Kentucky. This controversy is one the importance of which cannot be exaggerated, and is attracting much public attention and comment. The state officials of the various states, fearing that their authority may be prescribed, have been holding meetings and conferences attended by governors, state commissioners, and attorney generals, and each of these several classes of officials have appointed committees who are now preparing and submitting arguments, seeking to sustain the right and power of the several states to fix rates and charges, independent of the effect which such local rates may have upon interstate commerce. In many phases of this controversy, the old doctrine of "state rights" appears and is contended for.

The limits of this paper will not permit much of detail. The Minnesota case presents most clearly the interstate commerce question.

In this case, the Railway and Warehouse Commissioners of Minnesota, by an order, reduced the maximum rates for the transportation of general merchandise within that state from 20% to 25%; later the legislature passed an act reducing passenger fares in Minnesota 33⅓%, and subsequently the same legislature passed an act making an additional reduction upon the commodity rates, as fixed by the Railway and Warehouse Commissioners, of some 7.37%.

In proceedings commenced in the United States Circuit Court, the rates so reduced were sought to be enjoined, not only because they were confiscatory, but for the reason that such rates "burdened and regulated interstate commerce on said railroads."

The interstate commerce question is peculiarly emphasized by local conditions in Minnesota. Duluth, Minnesota, and Superior, Wisconsin, are separated only by the state boundary line. The same situation exists as between Moorhead, Minnesota, and Fargo, North Dakota; Grand Forks, Minnesota, and Grand Forks, North Dakota; Breckenridge, Minnesota, and Wahpeton, North Dakota. These several cities are all engaged competi-

tively in the same character of trade, industry, and commerce. They all distribute tonnage from their respective points throughout Minnesota, and must necessarily rely, for any sort of continued prosperity, upon the right of equal competition in the commerce of that state. If the Minnesota cities are the beneficiaries of the radical reductions made by the Minnesota authorities, and the cities just within the Wisconsin and North Dakota boundaries are not permitted to enjoy similar reductions, in the way of interstate rates, such a situation would destroy the commerce of the cities outside of Minnesota, would build a wall of protection about the boundaries of that state, and would lead at once to reprisals on the part of the commissions and legislatures of Wisconsin and North Dakota.

A situation of this kind, if permitted in one state, would at once be taken up in the several states of the Union, and would result, through the efforts of local authorities to protect their own interests, in the destruction of all interstate rates, and, as local rates are fixed in many instances by legislatures and other public bodies without adequate hearings, or due consideration, and without any expert knowledge on the subject, bankruptcy and ruin as to the carrying companies would speedily result. A precedent of this kind would effectually destroy the great volume of interstate commerce, and would permanently change the present great centers of distribution.

On the hearing of this case, Judge Sanborn, of the United States Circuit Court of Appeals, sitting as a Circuit Judge, sustained the contention of the railroads, and enjoined the enforcement of the rates. His opinion shows great industry, research and ability, and contains a review of all the law upon this subject.

The rights of the railroads, so far as this interstate question is concerned, rest upon the commerce clause of the Federal Constitution, which provides:

> "Congress shall have power to regulate commerce * * * among the several states."

A clause, so far as it applies to commerce among the several states, of only eleven words, which has been the subject of endless debate, and its construction by the courts of this country has filled many volumes; a clause so elastic that it has been able to keep step with the march of progress from the time of the most primitive means of transportation and communication to our present modern facilities, in which distance is annihilated, and messages forwarded with the rapidity of thought.

Judge Sanborn, in his opinion, lays down rules defining the lines of jurisdiction as between the state and federal authorities, which are full and complete. In speaking of the power to regulate commerce, the court, in this opinion, says:

"The power to regulate commerce among the states was carved out of the general sovereign power by the people when the national government was formed, and granted by the Constitution to the Congress of the nation. That grant is exclusive. The United States may exercise that power to its utmost extent, may use all means requisite to its complete exercise, and no state, by virtue of any power it possesses, either under the name of police power or under any other name, may lawfully restrict or infringe this grant, or the plenary exercise of this power; for these are paramount to all the powers of the state and inhere in the supreme law of the land."

Again, the court says:

"If the plenary power of the nation to protect the freedom of and to regulate interstate commerce and the attempted exercise by a state of its power to regulate intrastate commerce, or the attempted exercise of any of its other powers, impinge or conflict, the former must prevail and the latter must give way, because the Constitution and the acts of Congress passed in pursuance thereof are the supreme law of the land, and 'that which is not supreme must yield to that which is supreme.'"

And, further, the court said:

"It is the effect, and not the terms or purpose, of state regulations of its local commerce, that determines whether or not they so substantially burden interstate commerce that they violate the commercial clause of the Constitution. And this is a judicial question which each court must determine on its own responsibility on the special facts in each particular case, and in the determination and decision of which it 'must obey the Constitution rather than the law-making department of the government.'"

As sustaining the rules laid down by Judge Sanborn, many expressions of the Supreme Court of the United States affirming the controlling power of Congress in interstate matters can be found.

In one of the early cases (Gibbons vs. Ogden, 9 Wheat., 1), Chief Justice Marshall said:

"The power of Congress, then, comprehends navigation, within the limits of every state in the Union; so far as that navigation may be, in any manner, connected with 'commerce with foreign nations, or among the several states, or with the Indian tribes.'"

And in a later case (United States vs. Coombs, 12 Pet., 72), the same court, speaking by Justice Story, said of such power:

"It extends to such acts, done on land, which interfere with, obstruct, or prevent the due exercise of the power to

regulate commerce and navigation with foreign nations and among the states."

And in a later case (Groves vs. Slaughter, 15 Pet., 449), the court said:

"The power of Congress to regulate commerce among the several states is exclusive of any interference by the states."

And in a very late case the Supreme Court of the United States said (216 U. S., 1):

"If the statute, reasonably interpreted, either directly or by its necessary operation, burdens interstate commerce it must be adjudged to be invalid, whatever may have been the purpose for which it was enacted, and although the company may do both interstate and local business. This court has repeatedly adjudged that in all such matters the judiciary will not regard mere forms, but will look through forms to the substance of things."

By these repeated holdings the Supreme Court of the United States has so frequently upheld the controlling power of Congress to regulate, without interference on the part of the state authorities, interstate commerce, and the federal courts have so frequently held that any attempted regulation on the part of the several states, no matter what its form may be, which directly burdens or affects interstate commerce, is invalid, that there would seem to be much justification in the expressed belief of those who have given this subject attention that the Supreme Court will affirm the opinion of the Minnesota case.

A decision by the Supreme Court of the United States affirming Judge Sanborn's finding, will do much to clarify the present unsatisfactory situation. It will tend to nationalize the business of the great interstate carriers, and place them, so far as the vital question of income is concerned, under one dominant and controlling authority, and, if such a conclusion is arrived at, we believe and hope that it will be the beginning of a new era of permanent and lasting prosperity for the great transportation interests of this country, the successful operation of which is so necessary to our continued national growth and prosperity.

I believe that it is inevitable that the control of these great interstate carriers must be nationalized. Take a system like the Rock Island Road or the Santa Fe Road. The Rock Island runs through fourteen different states. Every two years it is subject to the burdens of legislatures, each supreme in its particular state, and as the train passes over the entire line of the system there are conflicting regulations. We have an example of it in Iowa. The North-Western line, running from Council Bluffs to Clinton, passes through sixty miles within incorporated cities and towns. Each town has a speed limit of six miles an hour.

If we obeyed the law it would take us ten hours to run through the towns between Council Bluffs and Clinton, and our fast trains make the entire distance from Clinton to Council Bluffs in nine hours and a half. We have a law which prohibits men from working longer than sixteen hours. Then we have another which prohibits us from confining cattle longer than twenty-eight hours.

Quite often we come to a point where either the limit of the twenty-eight hours for live stock or the sixteen hours for the men is reached. This sometimes occurs at a station where there are no accommodations for the men or facilities to care for the stock, and so we are between the upper and the nether mill-stones. There are times when, if we stop to unload the cattle, we have no accommodations for the men, or, if we let the men rest, we have no place to unload the cattle, and, in the interests of humanity, we are occasionally obliged to violate both laws.

Since the Supreme Court of the United States has determined the right of governmental control, the most industrious factories in the land have been the various state legislatures, each vying with every other one, to see how many laws they can enact, and all of them without much regard to the practicability of their enforcement.

Discussion.

President Chamberlain: I think any of those who have been connected with railroads realize that there has been legislation, and there is legislation still pending, both on the part of the state governments and of the national government, that to a man who has spent his life in railroad work appear not to have received the amount of study and thought that matters of such importance should receive. I have in mind now the regulation of the Interstate Commerce Commission requiring the placing of ladders at each end of both sides of box and gondola cars,—that is, on all cars on which freight is moved,—which to any transportation official, any switchman, any railroad conductor, or brakeman, would probably appear absurd; but from the present condition of things it looks as if we may have to comply with that regulation before long. In other words, we shall have to put twice as many ladders on our cars as are necessary, or as any reasonable brakeman or switchman or railway official would require, because the Interstate Commerce Commission says we must do it. However, I have always believed, and still believe, that these problems will eventually be worked out satisfactorily by the government.

One thing which Judge Davis has mentioned has probably come to the attention of every railroad man who has looked into the subject at all, and, in fact, is the important point in his address, that we look forward now to government control—that is, con-

trol by the national government—as the ultimate relief from the petty annoyances which have been inflicted upon the railroads by the various state governments.

W. E. Symons, M. W. S. E.: This paper is so thorough and complete that there is practically no room left to say anything in addition to it, unless it might be to supplement and indorse many of the interesting and valuable points of information that have been brought out. I myself would not think of offering any criticism, for I see no ground for such thought, and I would not feel competent to criticise.

A few points in connection with the paper have occurred to me, however: In all matters of this kind it is sometimes interesting to know what the trend of thought has been among other leading minds who have studied similar questions, and particularly what their thought has been at some remote period as compared with the present, especially when we are studying a question that has been passing through a period of transition, as it were, similar to that of the regulation of our railroads. With this thought in mind, I have taken extracts from the remarks of three gentlemen prominent in the railroad world, which I wish to offer, with the author's permission.

I have in mind three very distinguished gentlemen, whose opinions on matters of this kind are considered valuable in America and abroad. One is President E. P. Ripley, of the Santa Fe Railway System, who, as most railway people and a large part of the reading public know, is one of the leading railway presidents, and those who are familiar with the experience of our railway officers in detail, know that Mr. Ripley's training came through the traffic department. Therefore he has been brought closely in touch with all such questions as those which are embraced in the subject matter before us. The second gentleman is the Honorable John C. Spooner, of Wisconsin, and the third Mr. W. M. Acworth, the English authority on railways.

Some two years ago President Ripley, at a public meeting, spoke as follows with reference to the Interstate Commerce Commission:

"Upon the passage of the law, that which had been looked upon as perfectly proper and as the working of natural competitive forces became illegal and criminal. The railroads generally accepted the law and made an honest effort to observe it. The mercantile community did not: indeed, they openly defied it, soliciting rebates unblushingly and threatening with a loss of their tonnage those roads who would not succumb. The Interstate Commission, new to its duties, contented itself with comparatively unimportant decisions and practically did nothing to help those railroads who desired honestly to carry out the provisions of the law; and, as a result, within a year of the passage of the law it was quite generally disregarded. A few railroad men were fined, a few shippers convicted, and almost immediately pardoned, the law fell into disrepute; a condition disgraceful alike to the government, the shippers and the railroads, and especially distasteful to the latter, but exactly what was to be expected.

"The result was the passage of the so-called Elkins Bill, and later the Hepburn Bill, which, while amateurish and in many ways vicious, have effectually stopped the rebate system—a result for which we may all be thankful.

"In all the controversies that have led up to this almost complete control of railroad earnings and railroad policies by governmental agencies, the railroads have, as a rule, acted in active opposition. They have not been unanimous; some of us were willing to accept it long before it became a fact, but the majority could see nothing in it but disaster—it is too early to say which was right—perhaps an earlier acceptance of control would have made the control more lenient; perhaps its early acceptance would, on the other hand, have bound the chain more tightly. But the fact remains that while the basic principle of absolute equality as to rates has been accepted by the railroads gladly and in all good faith, and they have also accepted the principle of governmental regulation, the scars of the conflict remain and a large section of the public still suspects and misjudges us. It is true, of course, that in the rapid development of our business and in the exigences of a most exacting profession there have been abuses and lapses, but I maintain that the standards of fair dealing and commercial honesty in our business has been as high as in any other."

This was in November, 1909, and while much progress has been made in the way of harmonizing conflicting interests and the views of men prominent in the railway world and in our national affairs, yet we are far from a complete solution of many of the more important questions, and Mr. Ripley's remarks very aptly indicate the general sentiment and feeling which existed among the leading railway men of the country at that time.

Passing from the remarks of a most distinguished railway president to one equally distinguished as a statesman and lawyer, I next quote from the public utterance of the Honorable John C. Spooner, of November, 1909, with respect to the Interstate Commerce Commission, and the effect of its operation:

"I have seen it proposed lately that the Commission should have the power to fix a rate, and that that rate should be final until a final judgment setting it aside was reached. What becomes of the constitution under such a law as that? A railway company, as I have said, owns its property. It renders a compulsory service to the public over its own property, with its own equipment, with its own employes, and at its own risk, and is entitled to a fair compensation, based upon the fair value of the property which it devotes to the public convenience, and the Supreme Court has held that property cannot be taken—because the use of property is the property—cannot be taken for the public use without just compensation, and if the state, the legislature, or the Congress may authorize a commission to fix a rate as reasonable and fair, beyond which the railway company may not charge for services it renders, and require it to observe that rate until the final adjudication as to whether the rate is reasonable or not, and after the lapse of months it is decided that it was unreasonable, how can the railway company recover the great sum in unreasonable rates which it had lost? It is a taking of a private property for a public use without just compensation, and I deny the constitutional power of Congress to do that thing. I admit the power and the exercise of it to the fullest extent to so far regulate railway corporations as to secure to the public a faithful discharge of all their duties to the public at reasonable rates, and under fair regulations; beyond that I believe that the owners of the property ought to be permitted to manage the property.

"The business of railway management has become one of the learned professions. It calls for some of the brightest intellects in the country. It calls for the exercise of powers which, if devoted to the law or finance, or to any other business, would place those who exercise them among those at the head. It is one of infinite complication, and it is not to be supposed that railway commissions can manage railway properties as well as the men who have been trained from boyhood to that business. I have never questioned that the Interstate Commerce Commission, the Commission in Wisconsin, and other Commissions, earnestly set out to do the just and fair thing; but the trouble with this whole question is, and has been through many a year, that it gets too often into politics. I do not believe, myself, that questions of business ever ought to find their way into the political platform of the party any more than I believe that the relations of the employer to the employe, whatever the business may be, ought to become the football of party politics.

"I think the troublesome problems are approaching solution. The railway companies must obey the law. The people ought to see to it that the law which the railway corporations are obliged to obey is a just law, and that is to be ascertained only on painstaking inquiry, and not through the speeches of enthusiastic orators, or on the floors of Congress. It has got to be at times that where there was no other issue upon which a political contest could be fought out, the easy, obvious and last resort was, 'Let us go for the railroads'; or, as a governor of Minnesota once expressed it, 'Let's shake the railroads over hell.' The truth is that the interest of the railroads is the interest of the people. The railroad company is dependent upon the people for its life and its sustenance, and the people are no less dependent upon the railway company, and between the two there should be even-handed justice. They should be dealt with calmly, and legislation should only follow deliberation and investigation, and a law once enacted should be impersonally enforced, not enforced against some and left to fall into innocuous desuetude as to others."

Passing from the opinions of two distinguished Americans, a few extracts from the remarks of Mr. W. M. Acworth, M. A., the British authority on railways, in a speech delivered at Dublin, Ireland, in September, 1908, are indicative of the views held by prominent railway people in England with reference to the American situation. In discussing the subject, "The Relation of Railroads to the State," Mr. Acworth had the following to say with reference to the American railway situation:

"When we turn from the continent of Europe to the continent of America the position of affairs is startlingly dissimilar. The railroads of America far surpass in length those of Europe, while in capital expenditure they are equal. State ownership and operation of railroads on the continent of America is as much the exception as it is the rule in Europe.

"The Federal Government of the United States has never owned a railroad, though some of the individual states did own, and in some cases also worked, railroads in very early days. They all burnt their fingers badly.

"The question of public ownership and operation was, however, raised very definitely by Mr. Bryan during his candidacy for the presidency, immediately following his European trip, which, as he publicly stated, had convinced him that it was desirable to nationalize the railroads of the United States. For many weeks after Mr. Bryan's pronouncement it was discussed in every newspaper and on every platform from Maine to California. Practically, Mr. Bryan found no followers, and the subject was practically shelved. This was no doubt due to some extent to the ridiculous impossibility of his proposition, in which he seriously suggested that the Federal government should work the trunk lines and the respective State governments the branches. Even if anybody knew in every case

what is a trunk line and what is a branch, the result would be to create an organism about as useful for practical purposes as would be a human body in which the spinal cord was severed from the brain. Public sentiment throughout the Union was unexpectedly unanimous against it, and it is safe to say that the nationalization of the railroads is not yet in sight."

Remember, these remarks were made three years ago (1908.)

"In the United States not only has there been the passage by the Federal Congress at Washington of the law amending the original act to regulate commerce and giving much increased power to the Interstate Commerce Commission, besides various other acts dealing with subsidiary points, such as hours of railroad employes, but scores, if not hundreds, of acts have been passed by the various State legislatures. With these it is quite impossible to deal in detail. Many of them imposed new pecuniary burdens upon the railroad companies. All of them, speaking broadly, imposed new obligations and new restrictions upon the railroad companies. Not a few already have been declared unconstitutional, and therefore invalid by the law courts. And when the mills of American legal procedure shall have at length finished their exceedingly slow grinding, it is safe to prophesy that a good many more will have ceased to operate. But for all that, the net result of State and Federal legislation in the sessions of 1906 and 1907 will unquestionably be that after the reaction and repeal, the railroads of the United States will in the future be subject to much more rigid and detailed control by public authority than there has been in the past. The reign of railroad despotism, more or less benevolent, is definitely at an end; the reign of law has begun. It is only to be regretted that the quantity of the law errs as much on the side of excess as the quality on the side of deficiency."

In 1911 Mr. Acworth said:

"Two or three years ago I was discussing railway questions with one of the most distinguished professors of economics in the United States, and the professor, who has paid special attention to railroad matters, said to me: 'National ownership will not be a live question in the United States for fifty years to come, unless, indeed, England should nationalize her railways. In that case I admit the question might at once become urgent with us.' I am persuaded that my friend would not repeat his statement today. I have recently spent some time in the United States and have had considerable opportunity of learning what leaders of public opinion are saying, and, still more, thinking at this moment.

"Having regard not only to the actual situation in the two countries, but also to the very different temperaments of the two peoples, it appears to be more than possible that the United States will lead England in adopting a policy of railway nationalization; and this not after a lapse of fifty years, but in the near future. I recognize that in the United States there are obstacles to nationalization that do not exist in England. The instinct against government management and in favor of private enterprise is much stronger there than it is here at the present time, and the instinct is based on concrete facts; for it would, I think, be generally admitted that government agencies in America are on the whole less efficient than in England, and that a smaller proportion of the best brains of the country are enlisted in America in government service. Moreover, in America there would be greater danger—I almost feel tempted to say greater certainty—that, in the language of a distinguished professor, 'Politics would corrupt the railway management, and the railway management would corrupt politics.' Further, there is in America the certainty that nationalization of railways would raise in acute form the question, sometimes dormant but never dead, of state rights.

"For all these reasons it would seem that, if railway nationalization is to come in a great Anglo-Saxon community, England and not America will surely lead the way.

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"We have been accustomed to regard America as pre-eminently the country of unrestricted enterprise in railway matters. Speaking broadly, this was undoubtedly true until comparatively recently. It is certainly not true any longer. At the present moment American railways are distinctly more closely controlled by government authority than the railways of England.

"Federal control is comparatively new—its history only begins in 1887—and has only become serious within the last few years, but nowadays it is serious enough, in all conscience. American railways have led the world in the introduction of economies, the control of operation expenses by means of scientific accounts and comparative statistics.

"It may be added that state and Federal interference with the actual daily operation of the railways has already gone far and is steadily increasing.

"Peremptory orders to run such and such trains, to provide such and such accommodations on them, to build new stations here, to reconstruct lines there so as to avoid street crossings at grades, are increasing every year both in number and severity. Laws dealing with the provisions of safety appliances, regulating the number of employes on a train, or the number of hours these employes are to work, have been turned out by the hundred within the last decade.

"In this respect also the railways of the United States are subjected to interference more drastic and much more detailed than anything to which the English roads are subjected. And, whereas government regulation in England dates back to the beginning of railways, and has only been strengthened gradually and at considerable intervals, the whole mass of government regulation in the United States has been piled in the course of a few years on the backs of officers brought up under a system of almost entire freedom from exterior restraint.

"Not unnaturally the American railway men, buffeted by such fierce and frequent storms, coming on them from every direction at the same time, have lost their bearings. Government control, they say, they could live with, if it were steady, uniform and consistent. But government interference that is often self-contradictory, that never helps, guides or supports, that only objects, obstructs and forbids, in the end becomes impossible, for all private initiative is paralyzed. And to say that this is the position in the United States today is only to state what is obvious."

The foregoing clearly outlines the opinions three years ago, of the three eminent gentlemen mentioned, with reference to state and national control of our railways and the difficulties under which the railroads were laboring and possibly would have to labor in an effort to solve a difficult problem; while the third and last quotation from Mr. Acworth, the eminent English authority, fully confirms the statements of all three, at the three years earlier period, from which it should be very clear that American railway officers, in working out the problems presented to us this evening by the very able speaker, Judge Davis, have not only made great progress but have encountered more opposition and interference than the railways of others countries, but have yet before them a vast amount of similar work before an equitable solution can be reached of all these problems.

There is no question but that the American railways pay the highest wages to employes and receive the lowest rates for transportation; still their officers have been and are yet being sorely harassed by a multiplicity of conflicting interests or authorities, resulting in increased individual and corporate duties, added financial burdens and consequently reduced net earnings.

It would indeed be most gratifying to the owners and officers of American railways if the ends sought by our most progressive managers could be reached by mutual agreement on common sense, practical business basis in the operation of which the federal authorities would co-operate with, and assist the railways, thus eliminating any conflicting state laws that stood in the way of or hindered those whose efforts were in the interests of a unified plan or policy calculated to conserve the best interests alike of the railways and the people.

Although the obstacles yet to be overcome are great and the situation is at times grave, yet I have no doubt our railway officers will, in conjunction with the properly constituted authorities, acquit themselves as creditably in the final solution of all problems coming within the scope of the author's paper, as the leaders in any other business enterprise in America.

President Chamberlain: It has occurred to me while sitting here that while we are prone to look only at the difficulties which have beset the railroads, particularly during the last six or seven years, there have been some things done by government regulation which, in my opinion, have been a great benefit to the roads. The abolition of the indiscriminate use of the pass privilege has undoubtedly been a great benefit to all the railroads, and I think that the officials of the roads would agree that that is true. The practical abolition of the rebating system has been a benefit to the railroads. The solution which it seems to me must ultimately come in government control is the one outlined by Judge Davis, that the national government must ultimately assume the entire supervision of the railroads; and we hope that the time will come when the members of the Interstate Commerce Commission, or whatever at that time may be the regulating body, may be not politicians but trained railroad men. That, it seems to me, is what we ought to hope for as the solution of the railroad problem.

Judge Davis, we shall be glad to hear from you in closing, if you have anything further to offer.

Judge Davis: Mr. Chairman, I have nothing further to say, except to thank you gentlemen for the very hospitable greeting, and suggest that, while there is a great deal that is unsatisfactory that has grown out of the regulation of railroads, I think on the whole that it has been beneficial, not only to the roads but to the public. I believe that every railroad manager is glad that the system of free passes is abolished. I believe that the cutting out of rebates is not only a good economic but a good moral principle. In view of the many rivalries between the railroads there were certain abuses that the roads themselves could not correct, and while the laws were being enacted we were a good deal like a father chastising a wilful son, while the chastisement was going on we all of us kicked a good deal, but after it was over we felt it had done us good.

MEASUREMENT OF WATER, MEANS AVAILABLE AND THEIR RELATIVE ACCURACY.

Gardner S. Williams.*

Presented May 17, 1911, before the Hydraulic, Sanitary and Municipal Section.

My subject, *The Measurement of Water,* is one which we all come in contact with one way or another some time in our life, and the manner in which problems may be met and the degree of precision with which results may be obtained varies from what we might call rigid accuracy to the wildest guesses. There are, in a sense, two classes of measurements—those which are absolute and those which are inferential. Absolute methods of measuring water are practically two: measurement by weight and measurement by volume. There need not much be said about either of these, as they are familiar enough to most of you.

It might be worth while, however, to call attention to the fact that distilled water varies in weight between its temperature of greatest density and the temperature of 80 degrees—that is, within the range where we ordinarily meet with it in our outside work—such an amount that on the assumption of 62.4 lb. to the cubic foot, the maximum percentage of error is about 0.3 per cent. You can, therefore, readily see that the assumption of 62.4 lb. for the weight of water within that range of temperature is not likely to lead to any wild errors in determining the quantity.

Now, peculiarly enough—or perhaps I may not say peculiarly, but it is a fact which does not seem to be very generally understood—the question of weight of water other than distilled is occasionally raised, and so far as I am aware there has been very little investigation of the question as to whether water as it naturally occurs in streams or water which is turbid is of a higher or lower specific gravity or weight per cubic foot than is distilled water. At first thought we might say that if the water carries mineral matter in suspension we would naturally suppose it must be heavier. Such does not, however, appear to be the case. Some limited experiments were made on this subject while I was at Cornell University, and it appeared that a sample of reasonably turbid water—one in which a pin would disappear four or five inches below the surface in ordinarily diffused sunlight—is about 0.1 per cent lighter than distilled water; the reason for that being, probably, that the distilled water does not contain as much air as is ordinarily found in

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natural waters and that this mineral which is in suspension is quite likely to carry along with it an amount of air in excess of that which would be present in a clear water.

The measurement by volume, of course, depends for its accuracy upon the precision with which the dimensions of the measuring basin have been determined, and the exactness with which the surface of the water is located. The most accurate instrument that we know of, or that we use commonly, at least, for locating the surface of water, is the so-called hook gauge, which, as you probably know, was invented by Uriah Boyden in the early days of experimentation at Lowell, Mass. The gauge is manufactured by various concerns, more frequently by Gurley than anyone else, and with the customary lack of appreciation of the use for which the gauge is intended, the instrument as Gurley turns it out, is not particularly well fitted for its purpose. If you get an instrument from Gurley it will have a point something like a needle. Break this point off and file on a new one in which the angle at the vertex is about 90 degrees. The theory of the hook gauge is that as the point of the hook comes up through the water, it disturbs the film on the surface which is held together by surface tension; and if a ray of light is falling at the point where the hook is to perforate the water, at the instant that this film is displaced at all the angle of reflection is changed and there appears a dark spot in the light, so that for accurate work, where we can, we get an electric light or a lamp or candle flame in such a position that the ray of light will strike immediately over the hook and be reflected to the eye. A piece of candle floating on a block in the hook gauge pail makes a very good light. With the hook gauge and a good light, it is possible for an ordinary observer to read the surface of still water to about 0.0001 ft., and by repeated reading closer results can be obtained. The advantage of having a rather obtuse angle at the point rather than too fine a one is apparent, for if the light be not perfect and you bring an obtuse-angled point up through the film, it makes such a large disturbance before it really has perforated the film that it will be quite sure to attract attention, while if a long, slim needle-point is used, it may get through the surface and be sometimes as much as ¼ in. above it before this condition is detected. A good deal of work is done in the daylight—ordinary sunlight—or sometimes late in the afternoon in the twilight, when it is quite difficult to locate the surface with a needle-point.

It should be necessary to say that the hook gauge can be satisfactorily used only in still water; that if the water has an appreciable current it is impossible to get reliable readings with it, but that is a fact which has been overlooked by some text-book writers.

The next gauge, probably, in accuracy, is the so-called point

gauge, which is the instrument that was used by Weisbach in his experiments on the flow of water through orifices and pipes, where he measured the quantity of water volumetrically. The point gauge consists simply of a point which is brought down in contact with the surface. A very careful observer can read this instrument to within about 0.0003 of a foot.

A convenient method of locating the level of a surface of water is with a slim plumb-bob with an obtuse point, suspended on a tape, which can be dropped over the edge of a curved block on which there is a line to read from as a zero. This may be either let down in still water until the contact of the point with the water causes the surface to be raised by capillarity, or it may be swung gently until the point cuts a ripple in the water. If the water be running, it is usually necessary to swing it. The accuracy, of course, with this instrument is not quite so great as that of the point gauge, which may be worked down with a slow motion screw, but the surface of still water can be located with this instrument within something less than 0.001 of a foot, and it has the advantage that the target can be taken off from a leveling rod and fixed on a block so that the tape slides underneath and the vernier used for reading the tape. A source of error with this device is that in rough water there is always a tendency to read too high, because the bubble or skin film which is carried along by the point as it goes through the hollow of a wave leads one to think that the point is at the mean height of the vibration, whereas actually it is considerably above it; and generally, as a rough approximation, I have found that the time that the point is in the water should be about twice the time that it is out; that is, keep it in for about two-thirds of the period between waves.

A word should be said in regard to the stilling box or gauge pail where it is used in running water, and that is that it is possible that the surface of the water in the gauge pail may not coincide exactly with that in the stream; in fact, we can be quite well assured that it does not. The reason for this is that the height of the water in the gauge pail corresponds to the pressure head of the water at the orifice connecting to it, and if the water has a considerable velocity past that orifice the surface in the stream may be appreciably above the height to which the pressure will raise the water in the pail. That is not perceptible at low heads or low velocities, but in dealing with comparatively high velocities along the edge of the channel the gauge pail frequently will not indicate the actual height of the surface of the water in the plane where the orifice is.

A good many years ago, Mr. Hiram F. Mills made a series of experiments from which he concluded that when the orifice was at right angles to the direction of flow, the water in the hook gauge pail would be at the elevation of the water in the

stream; and so far as his observations went, with the velocities with which he was dealing, that seemed to be a fair conclusion. But dealing with higher velocities it will be found that the surface of the water in the pail is somewhat lower than the surface in the stream itself, and this evidently will have a bearing upon the measurement of head on a weir.

The next volumetric method of measurement is by the so-called displacement meters, and it need only be said that those instruments necessarily have to be rated. Of course the large ones permit an appreciable amount of water to pass through them without registry, and the larger the size the more can get through. It is, however, really surprising to discover the degree of accuracy found with the disk and piston meters on small streams. Streams of water that it would almost seem would go through without displacing the mechanism at all actually do cause a certain amount of registration; and, like a good many other things that come in for more or less criticism in this life, the water meters are much better than they are usually supposed to be.

We have next the inferential methods of measurement, in which, instead of measuring the actual quantity of water, there are measured certain factors or functions which regulate or control it, and the first one of the inferential methods may be said to be the orifice. In dealing with orifices, engineers and everybody else usually take the easiest way and measure the head from the center of the orifice. When this is done, it is found that the coefficient of a sharp-edged orifice will vary from about 0.6 to 0.63. While this is not a very large variation—something less than 2 per cent of error, if we take a mean coefficient—yet if one takes the trouble to integrate the head on the orifice and determine the center of pressure, it will be found that the coefficient is confined within much narrower limits. If the head be measured from the center of pressure on the orifice, rather than the center of the orifice, that coefficient, according to the best experiments, is practically constant for the rectangular orifice at about 0.604 and for the circular orifice at about 0.597. Hence, if a value of 0.6 be taken, the error introduced will be so small that it may be neglected in any case likely to be encountered, where full contraction exists on all sides. The error of orifice measurement occurs as frequently in the determination of the area of the orifice as in the determination of the head or an incorrect value for the coefficient.

The nozzle may be looked upon as a variety of orifice, and while its coefficient may vary anywhere from 0.97 to about 0.995, a value of 0.98 will ordinarily be within 1 per cent of the true result.

The Venturi meter is really a nozzle. The only difference between that and the ordinary nozzle, as we think of it, is that in the nozzle we estimate the pressure outside to be atmospheric,

while in the Venturi meter we measure the pressure at the outlet to the nozzle, *i. e.* at the throat of the meter. The Venturi meter is a very useful instrument, and under conditions of proper setting it is a very accurate one. If it be so set that the water comes to it without disturbance through a straight line of pipe, the meter can be depended on certainly within 2 per cent; but if it be set just below a curve, the results are not quite so favorable. In fact, some experiments which have been made with the same meter located in a straight pipe and located on an elbow, as the meter is sometimes set on a by-pass, indicated a difference of something like 4 per cent in the indications of the meter for the same reading when the quantity of water was measured by weight.

The next of the inferential devices to be mentioned is the weir, which follows the orifice naturally, as it is the orifice cut in two in the middle or cut off near the top, the water escaping with a free upper surface. There is frequently some misconception of the real definiteness of our knowledge of the flow over weirs. The weirs with end contractions, after all is said and done, is rather an unsatisfactory instrument to use. In fact, the usually accepted law for the effect of end contractions is only an approximation, and for that reason I would recommend using the weir without end contractions wherever possible, except in those cases in the field where the construction of a weir without end contractions would be a matter of considerable difficulty, and where the accuracy of measurement is not required to be within less than 1.5 or 2 per cent, but for the most accurate work more reliable results may be obtained with the weir with the end contractions suppressed. As to our knowledge of weirs, it appears that what most of us rely upon in this country are the seventeen experiments made by James B. Francis of Lowell, Mass., on a weir which was 10 ft. long, on which the heads measured ranged from 0.73 to 1.06 ft. The quantity of water that was delivered varied between 21 and 34 cu. ft. per second. Those are the results upon which the so-called Francis formula for weirs without end contractions is based; and it is probably the highest evidence of the accuracy, care, and faithfulness of Mr. Francis' work that his formula, even today, when extended to practically twice the limits that he put upon it, still comes apparently within 2 per cent of giving a correct measurement.

Fteley and Stearns were the next investigators on the flow over weirs usually classed as worthy of consideration, since the European investigators preceding them dealt with such small quantities of water and under such irregular conditions that their results are chiefly valuable for special cases. Fteley and Stearns made thirty experiments on a weir 5 ft. long, in which the head varied from 0.07 ft. to 0.82 ft., and the quantity from 0.36 to 13 cu. ft. per second. They then made ten experiments on a weir

19 ft. long, on which the head varied from 0.46 ft. to 1.6 ft., and the discharge from 20 to 130 cu. ft. per second. Theirs are by far the largest quantities of water that have ever been handled over a weir in which the volume was determined by a method of absolute measurement.

Bazin, who probably is entitled to stand today as having finally put the work upon weirs on the most satisfactory basis, made sixty-seven experiments upon a weir two meters, or 6.56 ft. long. The heads varied from 0.19 ft. to 1.01 ft., and the discharge from 1.98 cu. ft. to 23 cu. ft. per second. In order to get higher heads he then cut the weir in two, making it half as long (3.28 ft.), and made thirty-eight experiments on that, in which the maximum head was 1.34 ft., and the discharge ranged from 0.95 to 17.5 cu. ft. He then cut the weir in two again, leaving a length of 1.64 ft. or about 20 in., and on this he made forty-eight experiments, getting a head of 0.18 ft. higher than Fteley and Stearns had gotten on their weir 19 ft. long, using a maximum on that weir of 13.5 cu. ft. of water per second, or just about 0.1 of what Fteley and Stearns used.

Each of these investigations has given us a formula, and they are probably all familiar to you. The one that most of us use, because we can remember it, is the Francis:

$$Q = 3.33 L H^{3/2}$$

where Q = discharge in cubic feet per second
L = length of weir in feet
H = head measured from crest of weir to still water above.

Fteley and Stearns modified this very slightly to:

$$Q = 3.31 L H^{3/2} - 0.007 L$$

and adopted a general correction for velocity of approach, namely, one-and-one-half the head due to the mean velocity as indicated by the discharge computed with the observed head used as the total head.

Bazin brought out a more complicated formula, in which, by introducing a variable coefficient, he was able to provide for the effect of the velocity of approach, and that formula is probably today considered as being the most nearly accurate of anything that we have:

$$Q = \left(0.405 + \frac{0.00984}{h}\right)\left[1 + 0.55\frac{h^2}{(p+h)^2}\right] L h \sqrt{2gh}$$

where h is the observed head and p the height of the crest above the bottom of the channel of approach. I would, however, remark that Bazin's formula is not so reliable for low heads as that of Fteley and Stearns, which for heads under 0.2 ft. gives more accurate results. The variation between the computed discharges

by Bazin's formula and the measured discharges in his own experiments show a maximum variation for individual observations of about 0.5 per cent, and for the average of a series a variation from the volumetric measurement of about 0.1 per cent. In other words, we may say that water can be measured over a weir, I think quite safely, within 0.5 per cent. It may be, but it is not always. Taking the head as being properly determined and applying the several formulæ that we have—namely, the Francis, the Fteley and Stearns, and the Bazin—to the same experiments and keeping within the range of heads that the observers had, it will be found that these formulæ will all agree within about 3.5 per cent of each other. That is to say, taking Bazin's experiments, for instance, and computing for his lowest, and his highest discharge by the Francis and by the Fteley and Stearns formula and the Bazin formula, it will be found that the three discharges so computed for each condition, the measured quantity, agree within about 3.5 per cent. Silimarly, taking the Francis experiments, using the heads as determined by Mr. Francis, and applying the Francis formula, the Fteley and Stearns formula, and the Bazin formula, the same range will be found, and likewise taking Fteley and Stearns experiments. In other words, the error that is introduced by using one formula in preference to another is somewhat within 3.5 per cent for the heads experimented upon. That assumes that the head was read correctly, and that brings us to the question of what is the correct method of reading the head. Mr. Francis spent considerable time in investigating this subject, though I think that his investigations are frequently overlooked, and perhaps it is as well, for his conclusions, for once, and I think about the only time, are not entirely correct. This seems to be the only time Mr. Francis appears to have gone seriously astray, and for the conditions which he had, his conclusions were correct. At the particular heads at which he experimented, his results are accurate and I have confirmed them by my own experiments. But when we go beyond that and get to higher heads, a difference exists in the readings at the different points. Mr. Francis, in most of his experiments, read 6 ft. up stream from the crest of the weir and at a level very slightly below the crest. He does not state the exact distance that the orifice of his hook gauge pail was situated below the crest of the weir, but the illustrations show it to be very little below, where it must certainly have been in order that he might ascertain the reading of his hook gauge which corresponded to the crest of the weir. He also measured the head at the wall near the bottom of the channel and along a plank located longitudinally near the middle of the stream. He had a series of openings at different points connected to the hook gauge pail, and he concluded that it did not make any difference at which point the head was measured.

It happens when the head gets above a foot and a half it makes a good deal of difference. He was experimenting at about a foot, and at that point there does not seem to be any appreciable variation. Fteley and Stearns used the plank at the bottom. They also used in their large weir an orifice situated out in the stream, two plates being set side by side, an orifice in each connecting to a gauge; and these plates were adjusted until the gauge read the same on each side, thereby setting the plates containing the orifices parallel to the stream. The reason for adopting this apparatus was that the stream approaching the weir was affected by some piers a short distance above them. These orifices were located about 6 ft. up stream from the weir, near the level of the crest. Fteley and Stearns, and Francis each used small orifices, apparently not more than ¼ in. in diameter. Bazin, when he came to make his experiments, adopted a position 5 meters (16.4 ft.), up-stream from the weir and close to the bottom in the side of the channel, and an opening about 4 in. in dameter, which led to a considerable-sized pit in which his gauge was located. Bearing in mind the statement made above, as to the effect on the level of the water in the stilling box of the velocity past the orifice, it will be seen at once that Francis' orifice and Fteley and Stearns' orifice near the crest of the weir would have a considerably higher velocity of flow past them than would be the case with the orifice of Bazin, and it would be naturally expected that the indication of head, according to Bazin's method, would be greater than it would be according to either Francis, or Fteley and Stearns, and such is actually the case. Neither of these devices indicates as high a surface as will be found if one measure down to it accurately and carefully with a point gauge. In other words, the actual surface of the water is higher than indicated either by the Bazin orifice, by the Francis orifice, or by the Fteley and Stearns orifice, and while these variations are not important for ordinary measurement, at the same time if one attempts really accurate work, he should measure the head as it was measured by the one who devised the formula. It happens that comparing these three methods—that is, the orifice of Francis near the crest and the orifice at the bottom, and the orifice out in the plank at the middle of the stream at the bottom, and Bazin's orifice—for heads between 2 and 3 ft., these variations do not seem to amount to more than about 1.5 per cent; but with a head of 4 ft., the difference in the discharge amounts to about 4.5 per cent, and at higher heads the difference becomes still greater.

As you all know, there was a good deal of experimental work done at Cornell University on weirs, but there was little volumetric work done; in fact, there was none that was of sufficient accuracy to be classed with that of Francis, Fteley and Stearns, or Bazin. There were made, however, a great many

comparisons between the discharge over one weir and the discharge over another. We had a canal which was about 400 ft., or a little over, in length, and the upper 60 ft. was taken up with a head chamber, at the outlet of which was a weir 16 ft. long, and this was, as finally located, a little over 11 ft. above the bottom of the channel. Water passed over this weir and then through a channel which was 16 ft. wide and about 11 ft. deep to a weir situated at its lower end about 350 ft. away, which was likewise 16 ft. long, but a little over 6 ft. in height. We measured the water simultaneously over both weirs for considerable periods at widely varying heads, and found that the quantity as measured by these two weirs agreed within 0.5 per cent. So we may say that if our weir formula is accurate for one weir, we may expect it to be within 0.5 per cent accurate for the other. That was for the case of two sharp-edged weirs.

Having established that fact, a large number of experiments were then made on weirs of irregular form, but of course, those depended on the formula applied by the sharp-edged weir for determining their coefficients, and those results have been published,* and, in fact, some of them not long ago in the *Engineering News*,† and it is therefore unnecessary to discuss them here.

A word, however, may be said about the measurement of the profile of the jet as a means of determining the discharge. It frequently happens, particularly in reconnaissance work, that an engineer has an opportunity to measure the profile of the jet as it drops off an apron of some old dam or something of that sort, where he is not able to measure the head on the dam but can measure the height of the drop and the horizontal ordinate from the lip of the apron to the point where the jet strikes the water. I was curious some time ago, and in fact felt it of sufficient importance to make some experiments. A small weir was built over which water could be delivered at varying heads upon the apron of a dam. We first took the apron in its natural condition, that is, with the ordinary unplaned planks which had been in use for perhaps ten years, and more or less worn, and measured the flow over the weir and the flow over the apron. Then we put on some planed plank and tried that; and finally we put on some tin and got a smooth edge. We also tried the effect of inclining the apron down stream and inclining it up stream and having the apron horizontal. We found that the profile of the sheet of water, when we had a depth of water on the lip of more than an inch, would enable us to compute the discharge within 10 per cent in practically the worst case that we had, which was an ordinary rough apron—not as rough as I have seen in the lumbering districts where the apron was made

*Hydraulic Tables. Williams and Hazen. Wiley & Sons, N. Y.
†Engineering News, January 12, 1911, Vol. 65, p. 38.

of logs or poles without any pretense of having the top smooth, but such an apron as is ordinarily found. When we got the smooth plank or tin, we were able to get within about 2 per cent of the discharge as measured by the weir, when the discharge was computed by the ordinary formula that the distance of falling is equal to 0.5 gt^2, and the distance horizontally is equal to vt, where v is the velocity in feet per second and t the time in seconds. This method is one that can be often used when any other measurement would be difficult.

The chief source of inaccuracy is the measurement of the depth of the water at the instant it leaves the apron, and of course, the smaller that depth the greater the chance of error; this depth should be measured vertically, not normally to the apron.

The next method of measuring is included under the general head of velocity measurements, and the simplest, and I may say one of the best, is the method of rod floats. A good many of those who use rod floats are apparently quite innocent of the work which was done by Mr. Francis on them and the formula which he deduced. Mr. Francis considered that the curve of velocity distribution of the current from the bottom to the top was parabolic and made a correction to the velocity of the float for that portion of the stream which was not traversed by it. The formula which is not always to be found readily, is:

$$Q = Av = Av_1\left[1 - 0.116\left(\sqrt{\frac{d-i}{d}} - 0.1\right)\right]$$

In which A is the area of the stream, v the mean velocity of the stream, v_1 the mean velocity of the floats, d the depth of water, and i the immersion of the float.

Mr. Francis, in the second edition of his *Lowell Hydraulic Experiments,* modified the formula and got it in a little different shape, but from my own experiments I prefer the original form, which is that given here.

We made a great many float experiments at Cornell, where we had ideal conditions for such work. The channel was 16 ft. wide, in which water could be maintained at any depth from 4 ft. to 10 ft., and a very considerable amount of time, covering portions of two years, was spent in experimenting with rod floats and surface floats. It was found that in that channel, under the conditions which we dealt with, the gaugings with rod floats having immersions between 50 and 98 per cent of the depth of the water would check the weir within from 0.5 per cent to 1.5 per cent. A great many experiments checked the weirs between 0.5 per cent and 0.75 per cent. Of course, such accuracy as that cannot be obtained in a natural channel, because of the irregularities of the bed, and probably floats are very seldom run with

a greater degree of precision and care than was exercised at Cornell. We did not use stop watches, but our method of observation was to stretch two wires across at the up and down stream ends of the course and have an observer stand with an ordinary watch in his hand, the watches being compared every few minutes, and the observers exchanging positions from time to time. In observing, the watch was held so that the observer would catch the second hand, by simply dropping his eye from his observation of the float at the instant it crossed under the wire, and he was instructed to read the second hand as it read when his eye struck it, and not try to estimate what it was the fraction of a second before when he was looking at the float. The observer called the reading to the recorder who stood on a bridge and took the position of the floats as they went down. The floats were numbered so that their dimensions were known. That was simply the method of observation, and we took a course sufficiently long that an error in the reading of a second would not amount to more than 1 per cent. The ordinary time of travel we usually tried to have about 100 seconds.

It was with such work as that—observations being made by students, who, of course, became more or less trained as time went on—that we got these results checking our weir within from 0.5 per cent to 1.5 per cent.

At the same time representatives of the United States Geological Survey were making tests of current meters, comparing them with the weirs. We were never able to get the current meters to show as good results as the floats did. In fact, the error in the meter observations was just about twice that of the floats, and the most accurate results we could get with the meters was to apply the Francis formula to the meter gauging; that is, to assume that the bottom position of the meter represented the bottom of the float. Take the mean velocity as indicated by the meter over the depth it traversed as being the v_1 of the Francis formula and then apply that formula to it. When that was done the results much more nearly coincided with the weirs than when the average velocity was computed as is usually done.

The United States Lake Survey, however, has done some work with meters that so far exceeds in precision anything that anybody else has done that it is hardly to be spoken of in the same breath. During the past ten years gaugings have been made of the St. Clair River at Port Huron, the Niagara River at the International Bridge, and at a section some distance below the bridge where they had to operate from a boat, and in the St. Lawrence River at a point about 70 miles below Ogdensburg. Of course, these observations gave no opportunity of testing, volumetrically, the accuracy of the determination, and the evidence of accuracy lies in the observations themselves. In the

long series that was made at each place it so happened that there were numerous times when the gauge reading coincided with a previous one, and making comparisons under those conditions it appears that on the St. Clair River, the average of the variations was about 0.85 per cent from the mean, and the maximum variation of a single observation from the mean of its similar, as you might say—that is, from the mean of those that were taken with the same gauge reading—generally being not more than two, was 2.14 per cent. In other words, it appeared that every time that they got the same conditions there they were able to reproduce the discharge by the current meters, within 2.14 per cent of the mean of the observations considered.

On the Niagara River they did not do quite as well. There the maximum variation was 5.28 per cent, and the mean of the variation was 1.18 per cent of the mean discharge.

On the St. Lawrence River, apparently they did much better, for there their mean variation was 0.33 per cent, and their maximum a little less than 0.85 per cent.

It may be proper to say a word as to their method of observing, because there may still remain a question as to whether the accuracy of actual measurement is as great as these figures would indicate. Their method of observation was to locate certain points across the river and to make a series of measurements at points a tenth depth apart, determining the vertical curve. Then they determined the ratio of the mean velocity in that vertical curve with the known velocity of some point, which may be three-tenths, seven-tenths, or whichever one seems the most stable, and having determined these verticals across the river at intervals they then, in making a gauging, simply go across and read their meter at these controlling points. Of course, in that way they are able to take a gauging in a few hours, and it is the readings of these meters at the controlling points which are compared here.

The next thing that we would inquire is: what is the accuracy of those controlling points; that is, how nearly does the water assume the same velocity at those controlling points under the same conditions? That is a point on which, so far as measurements on a large scale are concerned, it is very difficult to arrive at a conclusion. The only information that seems to bear upon it is the measurements of water by means of the Pitot tube, where the quantity of water was afterwards measured by weighing, and it was found there that when the tube was located at the center of the stream in cases of normal flow, at the same point in the pipe, and the reading of the tube was taken, that the variation of discharge might amount to about 1.5 per cent for the same tube reading. That is, the velocity did not always appear to be the same at the point, for the same discharge, and I

surmise that this being the case with a circular pipe, it is very likely to be the case in an open river.

The next instrument which I would naturally take up would be the Pitot tube, and that is an instrument over which there has been, as a good many of you know, a good deal of discussion from time to time. I will only call attention to this one point tonight: that so far as the formula goes to be applied to it, we must not forget that if we increase the velocity of a particle of water we decrease the pressure, and that consequently the pressure at the center of a pipe is less under the conditions of normal flow than it is at the walls. Also that in the Pitot tube the pressure orifice reads the pressure that exists where the orifice may be, and the impact orifice reads the force of impact plus the pressure that exists there, and as the two orifices cannot be in the same identical position, the pressures may not and probably are not the same; hence the formula becomes more complicated than is usually stated. This is discussed at some length in the new *Civil Engineers' Pocket Book,* in which I think a correct statement of the Pitot tube formula is presented.

The Pitot tube as a water meter, when used at the center of a pipe, where the preceding pipe has been straight for a distance of at least 50 diameters (and better at 100 diameters), may be expected, having the tube properly rated, to give results to within 1.5 per cent of accuracy, and I do not know whether a much higher degree of accuracy can be obtained with it or not. In the hands of an ordinary observer I doubt if any such precision is obtained, because the possibilities of error in reading the gauge, the chances of air bubbles getting into the hose connecting to the gauge, and so on, render those things all difficult of actual determination, and I must say that while a recording device on a Pitot tube is a very useful appurtenance and for a great deal of work is indispensable, I never have as much confidence in the records of one of those recording devices as in the information obtained from observing the tube continuously. Not that the recording device records something that is not there, but it becomes a matter then of interpretation. Oftentimes the Pitot tube will be affected by something temporarily or continuously, something floating in the water or an air bubble, which will cause a change in the condition which the observer, if he is watching the gauge, will detect at once and be able to correct, whereas the recording instrument has no means of making allowance for it.

MEASURING THE FLOW OF WATER IN LARGE PIPE LINES

R. M. Hosea, M. W. S. E.*

Presented May 17, 1911.

About three years ago it became necessary to accurately measure the quantity of water flowing in three large pipe lines supplying the Minnequa Works of The Colorado Fuel & Iron Company, at Pueblo, Colo. Two of these pipe lines conduct the water from certain receiving reservoirs about 150 ft. higher than the works, and five miles therefrom, and form part of the gravity system of supply to which reference was made in the writer's paper, "A Colorado Mountain Reservoir," presented to the Society April 3, 1907.‡ One pipe is of 48 in., the other of 28 in. inside diameter, both of the wood stave, banded type. A third pipe line 28 in. diameter, also wood stave, leads from Lake Minnequa, about a mile distant, and 35 ft. above the works. All these lines are connected to a standpipe and to the general distributing system of the plant, and can be used singly or in combination as desired. There is considerable fluctuation in pressure and in the amount of use, governed to a large extent by the operations of a repumping station and six blast furnaces.

Upon first taking up the problem there appeared to be only two recognized methods of measuring the flow of water in large pipe lines: (1) By means of the Venturi tube and attachments; (2) By the use of the Pitot tube or pitometer apparatus.

A pitometer apparatus was available, but it was decided that in expert hands only, would results be satisfactory. It was found also that the cost of installation and operation of Venturi meters on the three pipe lines was greater than the results desired would justify. A thorough investigation of all known and accessible methods failed to disclose any cheap and simple "fool proof" apparatus for the purpose.

The insertion of a special form of current meter through an opening into the pipe in a similar manner to the pitometer, and registering its revolution by an electric contact point, was thought to be entirely feasible.

The construction of a special meter was entrusted to a well-known maker of current meters and he produced a device which, after some changes and modifications, was put into use. It consists of the usual meter cups carried on a vertical spindle with steel pivot below and a guide bearing above. The spindle and upper bearing are within a closed, cup-shaped chamber. By

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‡Journal W. S. E. August, 1907, Vol. XII, page 495.

means of a worm-gear-drive, a dial plate carrying a platinum point is made to contact with a tongue insulated from the body of the machine and connected by insulated wire through a hollow tube to the outside air. By attaching this in an electric circuit from a battery of one or more dry cells and a counting device, the revolutions of the meter are recorded. This device attached to a hollow tube of sufficient length can be inserted into the pipe line as illustrated in Fig. 1.

This arrangement, in the case of wood pipe, consists of a curved saddle carrying a 6 in. flanged tee which is strapped on

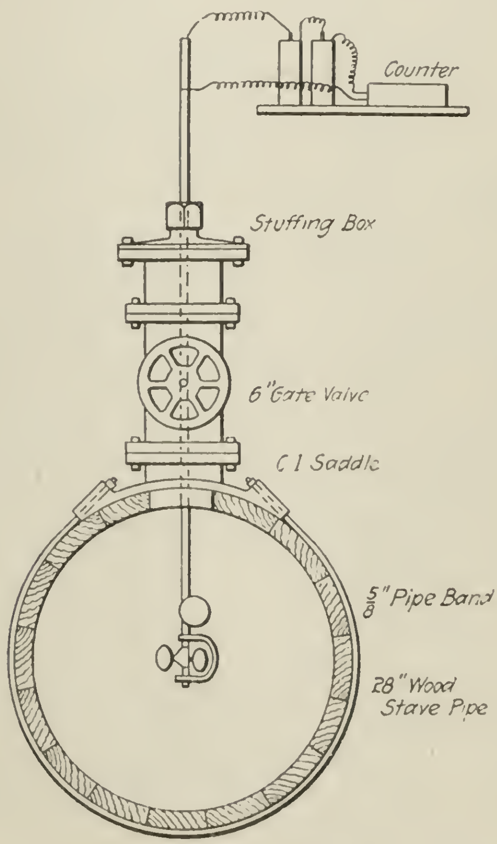

Fig. 1.—Current Meter in Wood Stave Pipe.

the pipe over a 6 in. hole. On this is placed a 6 in. gate valve and above this a chamber or nipple piece provided with flanges at top and bottom. The top is closed with a cover, which carries a stuffing box and gland. The cover and gland cap having been placed on the tube, the meter is inserted into the chamber piece, the cover bolted on and the gland packed. Then the 6 in. valve is opened and the meter pushed down through the disc opening of the valve to the required position. It is, of course, necessary that the device be of proper clearance diameter to pass the valve disc. The gland cap and stuffing box keep the hollow tube in a

vertical position and the tube must have sufficient stiffness to retain, at least approximately that position.

With such a device a velocity curve and coefficient of mean velocity can be experimentally determined for the particular pipe (in a vertical plane only), and the results of flow obtained are to that extent approximate. Some experiments made with a 28-in. pipe line at different rates of flow, where the discharge passed over a carefully constructed weir, showed a variation between weir measurements and meter measurements of 3 per cent, more or less. Similar vertical velocity curves obtained on a 48-in. wood stave pipe of the same character at different rates of flow gave substantially the same coefficient, but we are not able to check as yet against weir measurements of flow.

The meter registers the central velocity in the pipe and the coefficient of mean velocity is taken as 0.89 to 0.91, as determined by a number of tests. In other words, if mean velocity $= Vm$ and central velocity $= Vc$, in a wood stave pipe in clean condition $\frac{Vm}{Vc} = 0.89$ to 0.91.

The equation of this meter is $V = 2.32 \frac{R}{T} + 0.02$ determined between practical limits of velocity, as shown in Fig. 2.

In practice this device proved unavailable for continuous records owing to the difficulty of maintaining electric contacts, running down of batteries and certain electrolytic action or corrosion which destroyed the working parts in steady service.

A mechanical meter therefore was constructed, using the same style cups and spindle coupled to a light brass rod extending centrally upwards through a hollow tube attached to a closed box with a cover. The cover contained a plate glass window, intended to be bolted on to the box and made air and water-tight by means of proper gaskets. The central rod carries a striker at its upper end and is centered in a bearing, the lower end being carried on a steel pivot as in the ordinary current meter. The striker is made to successively engage with a ten-point pin-wheel geared to an ordinary six-dial counter such as is used in straight reading meters. In this manner the revolutions of the meter are registered positively as long as the water moves with enough velocity to move the cups.

If the total revolutions are read daily, by using the equation of the meter and the proper coefficient of mean velocity, the daily discharge (in cubic feet or gallons) is readily deduced.

Careful tests on our own rating station show that under low velocity too much water passed this meter without being registered, due to the friction of the parts. Efforts were, therefore,

made to improve the mechanical construction and reduce the friction coefficient.

A ball-bearing meter was then designed, containing a mechanical device (as shown in Figs 3a and 3b), which prevents

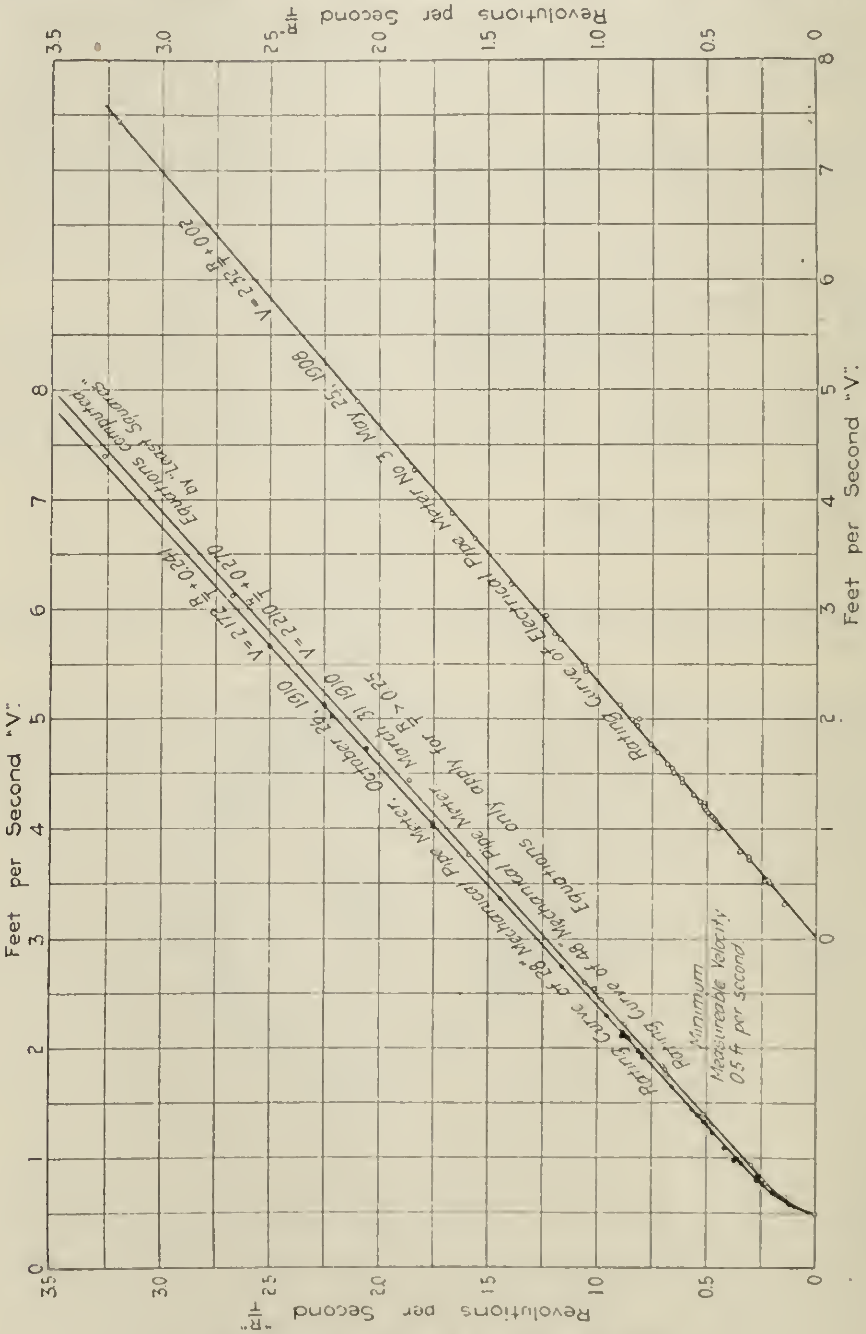

Fig. 2.—Rating of Current Meters.

jamming or locking between the striker and the ten pins on the driven wheel of the counter. In this device the striker is carried at the top of a light brass rod which is adjustably attached to

the upper or movable half of a ball bearing. The latter is of a form to be easily removed from its seat. An upper liner or side thrust ball bearing (not shown) can be used, but it has not proved necessary in practice. The lower end of the brass rod passes through a ball bearing at the bottom of the hollow tube, similar to a bicycle pedal, but the rod fits loosely so that it may

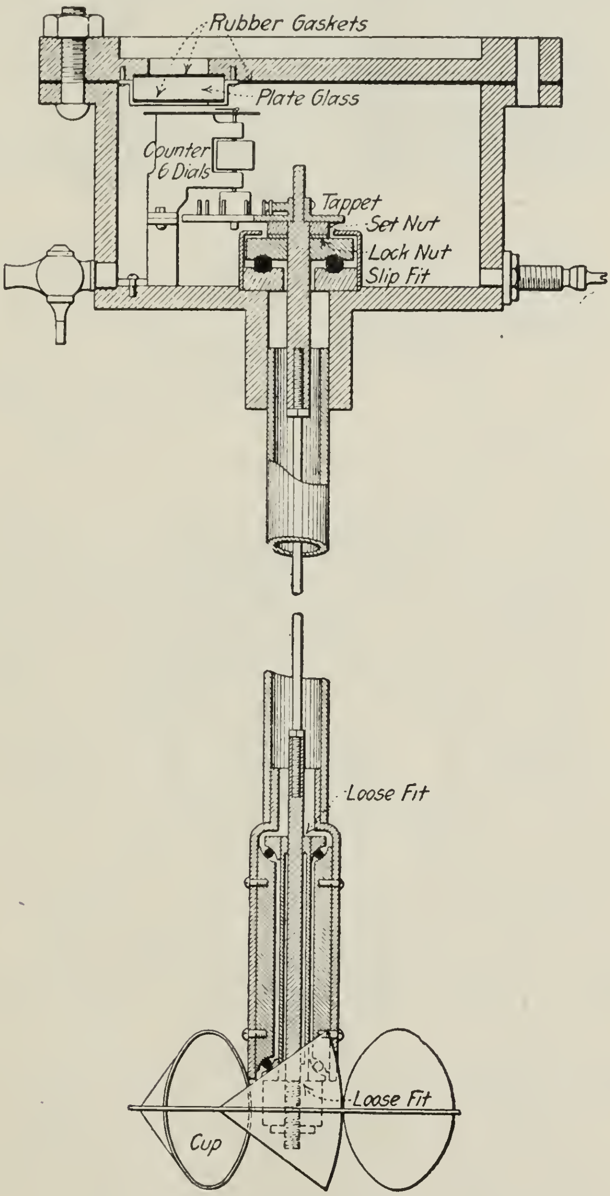

Fig. 3a.—Recording Current Meter.

turn the balls or slip in the hole as conditions warrant. This bearing takes up the side thrust due to the pressure of the water on the meter cups. The latter are removably attached to the brass rod which extends through the end of the hollow tube and by suitable washers and locking nuts, is given sufficient end

play. In operation the weight of the cups, washers, nuts, rod, striker, etc., is carried on a bronze ball bearing, and, as the whole can be made to weigh only a few ounces, the friction is very small.

Figure 2 shows the curve and equation of two of these meters. Figures 3a and 3b show the details of construction as found most practical. It is evident, of course, that a train of gears would accomplish the purpose of recording the turns of the meter wheel, but it is believed that less friction is produced by using the striker and pin wheel (Fig. 3b.) It is to insure the proper and continuous action of these parts that the special device shown in detail is used, in which there is no friction except

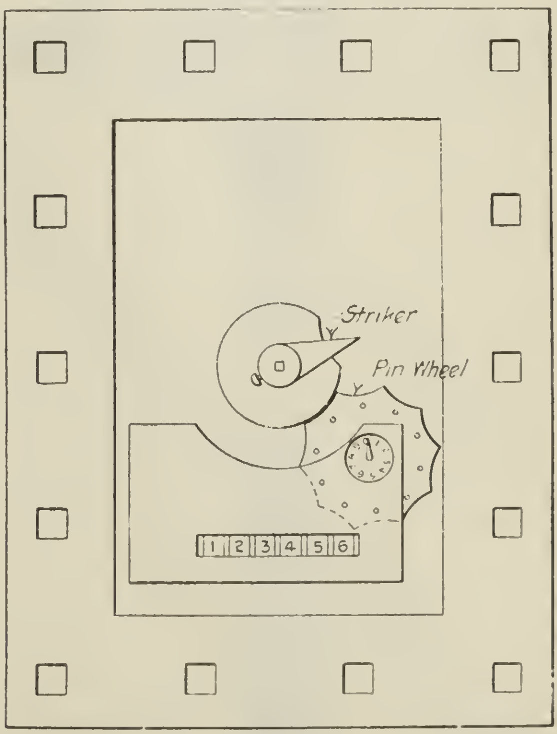

Fig. 3b.—Recording Device for Current Meter.

at the moment of contact of striker and pin, when the momentum of the parts is utilized. The box being air and water-tight can be pumped up with an automobile pump whenever necessary, which keeps out grit or mud and facilitates reading the dials. A blow-off cock enables sediment to be blown out. The box is made of aluminum, and, the other parts being very light, the meter is easily handled by one person. All bearings can be kept oiled if desired.

In case the balls, or any parts, wear or corrode, or the water is shut out of the line, the meter can be taken out and, if desired, rerated at a rating station and the new equation determined in a

few hours. The same device can be used on an iron pipe of any sort by attaching a tee or other connection large enough for a 6-in. valve opening and a stuffing box connection similar to that shown in Fig. 1. The meter as described and illustrated herein can be built for about $100, and the necessary fittings to attach to a wood stave pipe will cost about $50 more. In a cold climate some sort of protection for the meters will be necessary, such as a small brick house heated by some means in very severe weather. The house will cost about $300, making the total outfit cost $600 for two meters. In case a permanent automatic record is desired, an electric recording device can be attached in a similar manner to those furnished by several well-known manufacturers.

It is interesting to note that the mean velocity in wood stave pipe is here shown to be 90 per cent of central velocity, while reference to Proceedings of the American Water Works Association* shows that in large cast-iron pipes this coefficient ranges from 80 per cent to 85 per cent.

DISCUSSION OF PAPERS BY PROFESSOR WILLIAMS AND MR. HOSEA.

L. K. Sherman, M. W. S. E. (Chairman): Professor Williams referred to one type of gauge—a plumb bob—and I am going to take advantage of the chairman's position and illustrate one of those gauges which we used recently. It consisted simply of an iron rod running up from the surface of the water to an ordinary New York level rod. A vernier was attached to the iron rod and this rod was suspended by means of a string over a pulley to a slow-motion screw, as shown in Fig. 4. It made a splendid adjustment. The special feature of this whole device was that contact with the water was made, not by observation but by means of an electric A. C. current of 440 volts. One pole was in this contact rod and the other was in an iron weight immersed in the water. When the point of the rod touched the water, the circuit was closed and the current lighted a small electric lamp of about 2 candle power. With this device independent, untrained observers were readily able to read to an accuracy of 0.001 ft.

Daniel W. Mead, M. W. S. E.: I think the greatest difficulty in the measurement of water comes perhaps not so much from inaccuracy of methods as from inaccuracy in their application. In the field it is often necessary to use rather crude appliances, and frequently used under circumstances that are not favorable to accurate work; naturally, the results which are obtained are not so accurate as we might desire. Accuracy in this work is largely a matter of experience, and a matter of adaptability of the person who is making the observation. The degree of

*1907, page 136, Edw. S. Cole, "The Pitometer and Water Works Losses."

WATER GAUGE

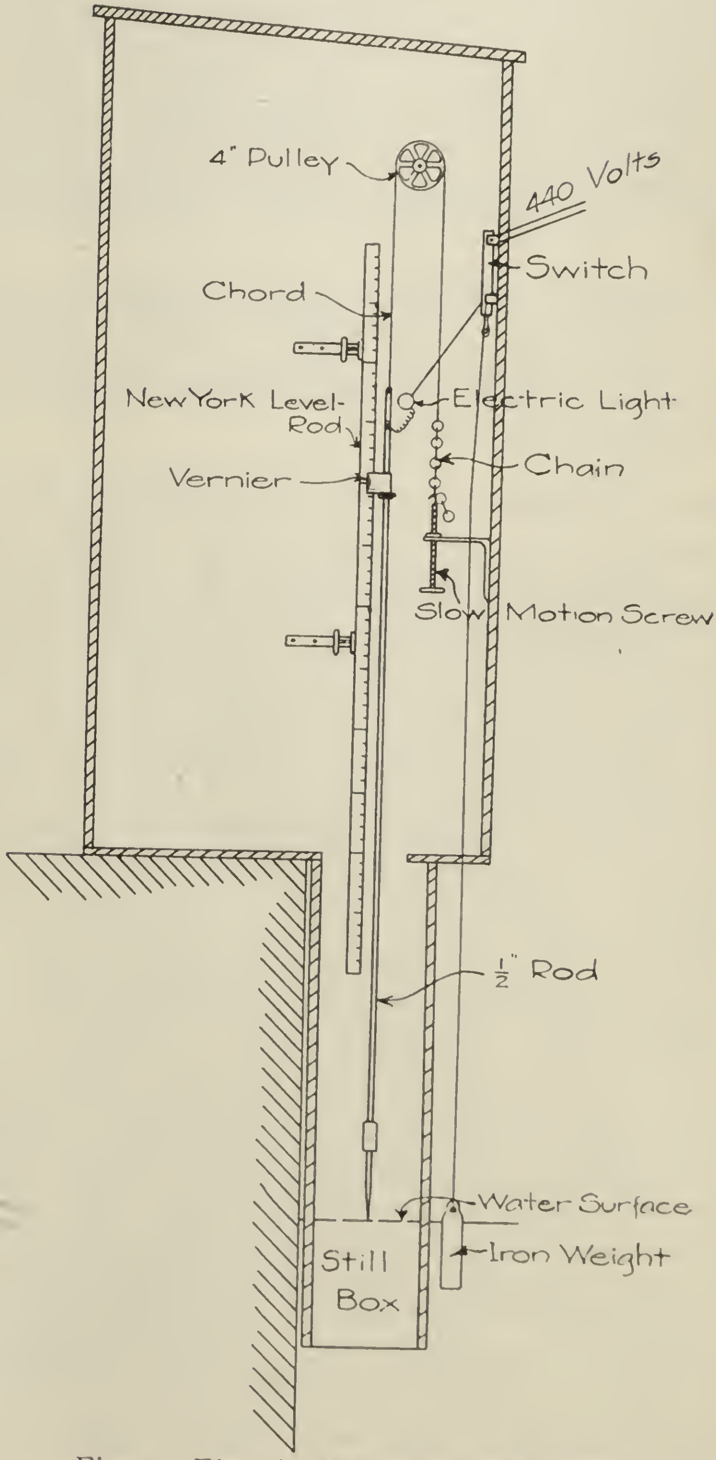

Fig. 4.—Electric Water Surface Gauge

accuracy to which Professor Williams refers can, I think, be obtained only by those who are experienced in making observations of this class; the average observations that are made in the field are apt to depart considerably from true results.

There is one line of observations on which a good deal of work depends that it may be well to mention in connection with what Professor Williams has said, and that is the observations of stream flow. At the present time a great many observations of the flow of streams are being made. Those observations are usually made by taking a series of current meter or float observations at some point where the channel is reasonably permanent, and from such observations plotting what is termed a rating curve of the stream. By means of this curve, when accurately constructed, the flow can be determined with fair accuracy by daily observations of gauge heights. I do not know how fully the limits of accuracy of this method of observation are realized. I think perhaps an idea of the nature of possible errors of such measurement may be obtained from a study of the recording-gauge records that have been taken by the United States Lake Survey in connection with their study of the flow of the large connecting rivers. In this work the height of the water is recorded for each moment of the day and is indicated graphically. The conditions on such rivers are widely different from those of ordinary streams, because the surface elevations of these rivers are controlled by the lake levels, and the large bodies of lake water are closely adjoining the stream. In these cases change of lake levels due to changes in barometric pressure are sometimes very great. I have noted in one of the diagrams published by the lake survey that changes in the level of the river (the St. Clair) as great as 2 ft. occurred within one or two hours, caused by the passage of a low or high barometric condition over the lake, which in turn caused a wave to sweep across the lake and radically affect the level of the water in the river. For such a case, a single observation or even hourly observations might lead to considerable error.

While such conditions are not at all applicable to ordinary streams, yet I think they do apply in a measure, and where gauge heights are only read once a day we are liable to secure only extremely approximate results. It is perhaps well to say that the extreme inaccuracy will usually occur at times of high water when a knowledge of the exact quantity of flow is not as essential as at periods of low water. During the low water, fluctuations are not as great, although they still exist to some extent.

In considering the accuracy of stream measurements, it is at once apparent that any change in the cross-section of the channel at the points where gauge readings are made is important, and frequently changes are very great. I had occasion

within the last year to examine the records on the Wisconsin River at Necedah, Wisconsin, where observations by the United States Geological Survey are available for a number of years. Checking up these gauge readings with measurements made at Kilbourn during the last low water period, I found that the observations at Necedah apparently showed nearly double the Kilbourn discharge as passing the Necedah station. One of my assistants was sent to Necedah and checked up the cross-section, made gaugings at that particular stage of water, and found that the cross-section had materially changed and that the gaugings that were made at that time, and other gaugings properly corrected, corresponded essentially with observations made at the same time at Kilbourn. I mention this matter in connection with the accuracy of water measurements, because stream-gauging methods are in very common use, and continuous observations of the flow of the stream for water power, irrigation, and navigation purposes are becoming very important and very common. It is very important that we should recognize the limitations and the degree of accuracy to which gauge readings can be depended upon.

J: W. Alvord, M. W. S. E.: I have listened with a great deal of pleasure and interest to Professor Williams' review of the fundamental methods for the measurement of water. It is always desirable for us to review these fundamental principles, and it is especially desirable to have a review of them from one who has given them so much attention and so much careful experimental study as has Professor Williams. We must always keep impressing ourselves with the refinement and the care that is often necessary in fundamental hydraulic data.

One of the practical problems, however, which confront the working engineer in the matter of water measurement, is the determination of the quantity of flow of extreme floods. It is obvious that here we are operating in a field in which the recorded experience is meagre and the practical difficulties great. Something more than the careful study of experimental work must necessarily come into play. At first thought it might be asked, "why are these flood measurements important?" It must be remembered that in cases of great and unprecedented floods it is necessary to determine as carefully as is possible the quantities of flow, because elaborate and costly works are usually necessary to prevent excessive damage occasioned by their recurrence. I have never found any very great help in the course of my reading, in the practical determination of such unprecedented floods as one is often called upon to estimate. The study of the best method for making such approximations must come through intuition, through common sense, through the application of the fundamental principles, of course, but combined with the appreciation of the practical difficulties of applying ordinary means of

measurement and the substitution of a process of reasoning from all of the observable data which can be accumulated. Perhaps I might illustrate what this means, by two examples:

It was my fortune to be engaged in studying the sewerage of the city of Columbus, Ohio, at a time when there occurred the greatest flood of recent years in the Scioto River, submerging almost the entire west portion of the city, carrying away many bridges and levees, and flooding a large section of the country. It had been realized that the flood water channel of the river opposite the city was insufficient in cross-section and that improvements must be made, and it became at once apparent that it was exceedingly desirable to know, just as far as it was humanly possible, the maximum quantity of flow of that particular flood. This involved an early and somewhat dangerous investigation by the City Engineer and myself and our progress to various points where we could observe and roughly determine the surface velocities and slopes, and later the cross-section areas and probable roughness of temporary channels. Many of the smaller of these channels were determined by the roughest kind of approximations, but in most of them—as was the case with the main body of the river—well-understood principles could be used, such as that of the submerged weir in the case of one important dam. Yet the whole study was necessarily a series of approximations of such data as slope of stream, of cross-section areas, and velocities, taken with as much care as could be had in a district where progress was difficult, where all the attention at the time was being concentrated on the rescue of people from the submerged houses, care for the wreckage, and the restoration of the water supply and lighting systems. Our estimates were the basis of a large expenditure, amounting perhaps to over $750,000 for the improvement of the river. Perhaps we came within 10 percent of truth, perhaps not within 15 per cent or 20 per cent of it, but in such a case even an approximation within 20 per cent was of tremendous value.

Another instance occurs to me which might illustrate the practical necessities of even an approximate measurement in such cases. This occurred in a devasted district near East Alton, Illinois, on Wood River. This stream flows down into the Mississippi River, out of the hills, and while it has a comparatively small water-shed, it nevertheless rolls up an enormous flood. Owing to the steepness of the slopes of its water-sheds, these floods in 1904 and 1905 carried away many of the railroad embankments, submerged many of the industries located there, and it became a matter of great interest—at first for the purposes of lawsuits and later for a project for the improvement of the stream—to know as nearly as possible what quantities of water passed down at the crest of the flood. A case of this kind, where personal inspection of the flood itself is not possible, is not so

satisfactory as is the opportunity for personal inspection as in the Columbus case I have mentioned, because much of the information obtained must of necessity be at second hand. Nevertheless, a study of the high-water marks and resultant slopes, cross-sections, and throttled points, where most of the water of the river would be confined in one cross-section, gives a fairly good basis for study. In the case in question, two engineers, collecting their data independently, came within 8 per cent of each other's estimate, and resulting works costing something like $350,000 will have to be predicated upon the maximum run-off so determined.

It has often occurred to me that more might be written and more study might be given to the best methods of approximating the measurement of enormous floods. I have frequently felt the weakness of the situation when called upon to do the best that could be done in such cases. These are the practical cases, which frequently come to the practicing engineer, and the importance of the results which depend upon them is very great.

Horace S. Baker, M. W. S. E.: I would ask Professor Williams one question in regard to the subject of Venturi meters. He mentioned the point, which we are all aware of in a general way, that curves near the meters affect the accuracy of the registration. Here in Chicago we have a number of meters in place and more to be set, mostly 36 in. and 42 in., on the discharge pipes of various pumping stations, and in practically every case the discharge from the pump pit comes up vertically and turns a 90° bend of about 15 ft. radius, and it is necessary to put the meter close to the station in order to get it on the single pipe line before it reaches the header or some branch line. I wondered if any experiments had been made as to the length of pipe affected beyond the bend, where the eddy is expected to occur.

Professor Williams: The distance through which the distortion caused by a curve appears to extend is somewhere in the neighborhood of 100 diameters of the pipe, but I doubt if the distortion beyond probably 25 or 30 diameters would make an appreciable effect on the meter; so that I would say that in a 48 in. pipe if you get your meter 100 ft. away from it, I do not think there would be much difficulty from it. The reading would probably be slightly affected, but I do not think that it would be a serious matter. At any rate, 50 diameters I think would eliminate any defect that could be detected in a Venturi meter.

Langdon Pearse, M. W. S. E.: I would like to ask one question of Professor Williams. What do you consider the accuracy of the rating of a current meter? I do not think that was touched on. At one time I had some experience with Mr. Freeman in Boston Harbor. We had several Haskell meters (from the Lake Survey) which were rated by us at Lawrence, Mass. It seemed to me at that time that the accuracy of the meter

would probably be the method of rating; that is, the accuracy of results obtained does not rest so much on the manipulation of the meter itself, but on the original ratings, and the conditions under which the rating is carried on, whether in running or quiet water.

Professor Williams: This matter of rating meters has received a good deal of attention. Some years ago I was rather strongly of the opinion that rating current meters in still water would not give a proper curve to apply in running water. I am still of that opinion as regards the Pitot tube, but I think I was in error in regard to the current meter. The United States Lake Survey a few years ago made a very interesting test of the rating of their current meters. Having rated a pair of meters in the ordinary way in still water they hitched two of their catamarans 200 ft. apart in the Detroit River and put a meter on each one. They then injected a bubble of bluing with a force pump into the water in front of one of the meters sufficiently far for it to attain the velocity of the water, and allowed it to float down past that meter and past the other, taking the velocity of the bluing as being the velocity of the water which passed the meters, and checked up in that way. The water velocity checked their ratings within 0.2 per cent as the mean of 76 observations. Of course, as has been suggested, the accuracy of any of these devices depends upon the accuracy of rating, and that again gets down to the accuracy of the observer. The figures I have given you tonight are, as Mr. Mead has suggested, results that can be obtained with the best. We can no more approximate what the ordinary, every-day lay observer will do, what his percentage of error will be, or what the reliability of his results is, than we can prognosticate what will be the average precision of his arrival at dinner. They are things that depend solely upon the personality of the individual and we cannot make any general statements regarding them. If we happen to know the man, we may be able to estimate that he will get within 5 per cent, 10 per cent, or 100 per cent of the truth; but if we do not know him, there is not much use trying to guess on that phase.

There is one matter that I would suggest in connection with the paper of Mr. Hosea, where he calls attention to the fact that the ratio of the mean to the maximum velocity in his pipe is in the neighborhood of 90 per cent. It occurs to me that we should know what the location of his meter was with reference to the inlet of his pipe or to any contraction or disturbance of the normal flow, because, taking the ordinary cast-iron pipe, we will find that the ratio may be anywhere from about 97 per cent to the normal ratio of approximately 83 per cent, and I suspect that the current meter in this case was located somewhere near the inlet of the pipe or possibly some distance beyond a curve, so that what we call the normal flow had been established. I can

see no reason why this ratio between central and mean velocity should be appreciably different in stave pipe than it is in other pipes, and such observations as have been made on such pipes elsewhere do not indicate that result. It is possible that his meter was located too near the entrance to the pipe to give him the condition after the flow was really established.

I fully appreciate the remarks of Professor Mead, and it was because of my appreciation of the lack of precision in the particular line of work to which he has referred that I hesitated to bring it into a discussion in which I was trying to talk of precision.

REACTANCE IN ALTERNATING CURRENT CIRCUITS

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The subject on which I wish to speak tonight is reactance. At first sight there appears to be very little to be said on reactance. The general impression of reactance is that it is an objectionable feature of alternating current circuits which impairs regulation, spoils the voltage control, and so should be avoided as much as possible. On the other hand, we see that in the last few years engineers are recommending the installation of reactances in all modern high-power systems, and that such reactances are being installed to assure the safety of the system. It is therefore desirable for us to look a little further into the characteristics of reactance to see whether it is really that unmitigated evil, as our earliest experience led us to consider it, and which it is still in the conception of many.

Reactance became of importance with the introduction of alternating current distribution. It is true the first industrial circuits were series alternating current circuits used for lighting by the Jablochkoff candle. They had a rather limited use, as the greater extent of application of electric energy for lighting, etc., came with the development of the incandescent lamp and the arc lamp. With these came the direct current circuit. The incandescent lamp led to the 110 and 220 volts constant potential distribution in the Edison systems, the development of which are our modern, huge central-station plants, as here in Chicago and elsewhere; also the arc lamp operated in constant direct current circuits, in series connection, from the Brush machine, as the highest development in that direction, which machine is now gradually falling into oblivion by being superseded by the series alternating current circuit and by the direct current circuit operated from rectifiers. The alternating current distribution was introduced again by the development of the transformer in 1886, and then as constant potential circuit of 52 volts, 110 volts, 220 volts, and here it was that reactance made itself felt. In these alternating current circuits the drop of voltage in lines, in generators, in transformers, was far in excess of that corresponding to the resistance of the circuit, far in excess of what it would be under the same condition in direct current circuits. The explanation of it was found in the electromotive force of self-induction. If an electric current flows through a conductor, there appears surrounding this con-

ductor a magnetic field; lines of magnetic force encircle the conductor. If there is a change of the current, this changing magnetic field of the current induces an electromotive force—the electromotive force of self-induction. With direct current, where the current is constant and so the magnetic field constant, this electromotive force of self-induction appears only in starting and in stopping the current. With alternating current, where the current continuously changes, the magnetic field also continuously changes, and there is continuously induced an electromotive force of self-induction which consumes voltage. This means that the investigation and calculation of alternating current circuits, of the drop of voltage in them, appeared very much more difficult and formidable than that of direct current distribution. It was only by the conception of the reactance, by replacing the analytical and mathematical investigation and calculation of this electromotive force of self-induction with the conception of an apparent resistance—an apparent resistance which consumes voltage and thereby represents the electromotive force of self-induction—that the dealing with such circuits was simplified.

This apparent resistance—which does not represent or mean the ohmic resistance of the conductor but which represents the effect of the electromotive force of self-induction of the magnetic field of the conductor—has been called reactance. It consumes voltage just like the true ohmic resistance, but it differs from ohmic resistance in that the voltage consumed by it is not in phase with the current, does not coincide in its variation with the variations of the current, but lags behind it 90°. That is, the reactance voltage is highest at the moment the current is zero, and the reactance voltage becomes zero when the current is at the maximum. The result is that the reactance consumes voltage but does not consume power.

This conception of reactance expressed in ohms as an apparent resistance, a resistance consuming voltage but not consuming power, meant a great advance in electrical engineering. It took many years to develop this term reactance as representing the effect of the electromotive force of self-induction on the voltage, and the inductance as representing the effect of the magnetic field. These terms were introduced and standardized only in 1893, as far as I remember, seven years after the transformer and alternating current distribution had come into practical use. They made it possible to deal with alternating current circuits almost as simply as with direct current circuits, by replacing the ohmic resistance of direct current by the combination of the ohmic resistance and this apparent resistance or reactance of the alternating current.

The first observation was that the reactance usually was much greater than the resistance; that the voltage consumed

by it was greater than that due to the resistance; that in lines, in circuits, there was a formidable reactance drop; that transformers had from 15% to 20% reactance; that generators had high resistance. The problem of the early years of alternating current distribution, then, was to control and eliminate this reactance drop, which spoiled the constancy of voltage and handicapped the alternating system, by designing lines, transformers and generators for the lowest possible reactance.

A great step in advance was made by getting to lower frequencies, by introducing 60 cycles instead of the much higher frequencies in vogue in the early years. This cut reactance more than in half; and then, by using only moderate sized conductors, by arranging the conductors so that conductor and return-conductor were adjacent, by dividing large conductors into a number of conductors, the reactance of transmission lines and distribution circuits was brought down to be comparable with resistance. Thus it ceased to be formidable, so that alternating current development could proceed to the introduction of secondary distribution—110 volt, 220 volt—similar to those in direct current systems. This was necessary to make the alternating current system an economical possibility by eliminating the terrific waste of energy as it existed when every consumer had his own small transformer. Still, one must realize that even today we cannot use alternating distribution conductors of as large size as they are continuously used with direct currents; we cannot use conductors of a million circular mils. Where a demand for power is so concentrated as to require the use of conductors of a million circular mils in the secondary distribution, there today the alternating current is still practically excluded. So in the center of big cities like Chicago, New York, etc., the direct current still controls and probably will always control, because the large conductors needed to convey those large currents which are required for the very concentrated demand are impracticable with alternating current. But where alternating current can be used, where the load is less dense, in most smaller cities in the country, there the reactance problem in regard to lines is practically solved, and the reactance has become comparable with the resistance so that it is no longer an obstacle.

The early transformers had from 15% to 20% reactance. That means on load the voltage drops materially, and when the load was induction motors the voltage dropped, well, to the vanishing point. That led, then, to the development of transformers of lower reactance by intermixing the primary coils and secondary coils, primary and secondary coils alternating with each other, leaving very little space between primary and secondary, giving thereby a transformer of low reactance, so that the reactance was brought down more and more. A con-

venient design used today in most smaller lighting transformers is a transformer with very long, narrow cores and one single primary and secondary coil overlapping each other. The average distance between the primary and secondary coils is very little; there is very little stray magnetism between the two coils, therefore very little reactance. The reactance of transformers has gradually been brought down and down until it is not formidable any more, until we now have transformers of 1½% reactance.

The same development took place in generators. Instead of massing the conductors in a single slot or a few slots, they were distributed in a number of slots, again breaking up the massing of the coils, lowering the reactance. Finally the result was that reactance in alternating current circuits of generators, lines, and transformers, was brought down so as not to be formidable any more. It ceased to be the enemy of the alternating system.

But industrial development proceeded farther. We must realize that as soon as reactance is down to the same magnitude as resistance, it is not formidable; not appreciable even, because it does not act like resistance, directly in opposition to the voltage, but acts in displaced phase of 90° lag, and so affects the voltage much less. But those changes in design which became necessary to lower the reactance also became necessarily of an advantage when we came to larger sizes of apparatus, to larger transformers, larger generators, especially when we finally found materials which could be worked at a higher density, like the silicon steels of low hysteresis loss of the last years. There is no limit any more on account of efficiency with the magnetic densities that can be used. We have, in apparatus design, gone beyond the point where reactance ceases to be an enemy, and so, while still in the minds of many engineers there is the old conception of reactance as an enemy, in reality in apparatus as it exists today it has practically disappeared. The reactance is so low that it does not come into consideration any more as impairing the voltage.

But reactance, even excessive reactance, is not always an evil. There are cases where reactance is useful. That had been recognized already in the early years. In 1894 the first application of that character was made and reactance used to improve regulation, to maintain constancy of voltage. Wherever synchronous machines—synchronous motors, synchronous converters—are used, reactance can be used to improve the voltage regulation, to control the voltage by what is now called phase control. The voltage consumed by reactance lags 90° behind the current. Therefore, where the current is 90° behind the supply voltage, with lagging current, the reactance voltage which is still 90° more behind the current, is in opposition to

the supply voltage, and so subtracts itself. In short, reactance then consumes voltage. But if we have a circuit where the current leads the voltage, where the current is 90° ahead of the voltage, or, turning it around the other way, where the supply voltage is 90° behind the current, the reactance voltage also is 90° behind the current, and the two therefore are in phase. In such circuit, with a leading current, the reactance voltage adds itself to the supply voltage. So if you have a circuit where you can vary the phase of the current—change it at will between lag and lead—you can vary the effect of the reactance voltage; make it subtract, that is, lower the voltage with lagging current, or add to the supply voltage by raising the voltage with the leading current.

The voltage consumed by the resistance always increases with increase of current, that is, the resistance drop always increases with increase of load, and the voltage should fall due to a resistance drop with increased load. If in such a circuit you can vary the phase relation, make the current lag at low load, and lead at heavy load, then at low load you can use the reactance voltage by lagging current to consume voltage, and at load you can by leading the current make the reactance raise the voltage. By changing the phase of the current from lag at no load to lead at heavy load, we can change the effect of the reactance from lowering to raising the voltage and thereby make up for the increasing drop of voltage by resistance. We can keep constant voltage at all loads, increase the voltage with the load, or reduce the drop of voltage which we would get without reactance due to the resistance. In short, we get a control of the voltage. But that means, in a way, a method of changing the phase relation of the current. That is done and can be done in synchronous machines—synchronous motors and converters—by change of excitation. At low excitation the current lags. At high excitation the current leads. If, therefore, in a synchronous machine we increase the excitation, then we change the current from lagging to leading and we also change the effect of reactance from lowering the voltage to raising the voltage. That has become the standard method in controlling the voltage in railway systems, such as long distance railways, using synchronous converters. With increasing load there would otherwise be a drop of voltage due to the resistance drop of the transmission line. By increasing the excitation of the converters with the load in the substation—which is done easily by a series field, by compound field winding—we cause the current to start lagging at light load, become leading at load, and so make up for resistance drop and get a perfect voltage regulation, or as nearly perfect as is desired by adjusting things.

The same can be done with synchronous motors. Naturally, where we have a converter which changes alternating to direct

current, it is more convenient, because the direct-current output can be used directly in a series field to vary the excitation. In a synchronous motor we would have to vary the excitation, by a field rheostat, or by some automatic potential regulator, like the Tirrell regulator. This is being done very frequently now; indeed, in many of the very large transmission systems, as in the West, operation is possible only by the extended use of synchronous machines, by this control of the field regulation to maintain constant voltage. The drop of resistance of the transmission lines which criss-cross the country is so great that we could not keep reasonably constant voltage anywhere by regulating the generating voltage in the hydraulic station. But synchronous motors at the distribution centers, operated by potential regulators in their field excitation, can locally control the voltage and give the required regulation. So here we find a useful application of reactance for regulating the voltage—for keeping constant voltage—that is, compensating for the voltage variation due to the resistance. Naturally, the first use of reactance for voltage regulation was made by calling upon the reactance of lines and generators. Having a separate generator for each converter supplying power on a transmission line, and then by over-compounding the converter field we could shift the current phase in the system from lag to lead and thereby operate upon reactance of lines and generator to lower the voltage at light load, or raise it under load. But that obviously is feasible only where each synchronous motor or converter has its own generator to act upon. Where, as is now always the case, there are a number of converters as substations operated from the same generator or from the same system of generators, we cannot use the generator reactance because it would not respond to each individual converter but it is in circuit with all of them. Very soon, then, it was noticed and marked that the reactance of lines is not sufficient to give regulation, and it became the practice to insert reactive coils at synchronous motors or converters. So the standard system of railway transmission for interurban lines and for long distance railways is to have substations operated from a transmission line, with step-down transformers and reactive coils, the converter being compound wound. The series field raises the excitation at load and shifts the current into lead, thereby utilizing the reactance for keeping a constant voltage at the brushes.

Naturally this useful employment of reactance in the form of reactive coils, combined with the surviving of the early conception of reactance as a harmful thing, has led to a number of ludicrous situations, where the customer specified that the reactance of the transformers must be less than 2%, and then paid for a reactive coil of 15% to insert in the secondary of the transformers. But that naturally is only a temporary condition.

However, this is not the only beneficial feature of reactance. Reactance is necessary in parallel operation of alternating current generators and in operation of synchronous machines, as synchronous motors or rotary converters. In the early days of the old high frequency single-phase machines, it was always claimed that these alternators could be run in parallel, in synchronism. Experimentally it was done; practically it rarely succeeded, because, due to very high internal reactance, the synchronizing current was limited. Then the causes tending to drive them out of synchronism were very great—high speed machines driven by high speed belts—so it was rather an impractical thing to operate in parallel until the arrival of the lower speed, lower frequency, larger unit of machine. The 60 cycle generators did operate and do operate very satisfactorily in synchronism. There have been many troubles with such machines where 60 cycle generators were operated in multiple and showed hunting—sometimes insurmountable hunting—but probably at least 75% of the cases of hunting were due to the engine governors, which did hunt against each other, and only rarely due to the machines. These machines had much lower reactance than the old high frequency machines, had much greater synchronizing power.

In the modern steam turbine alternator of much larger units, higher speeds, lower frequency, 25 cycle, the necessities of design resulted in the use of much lower internal reactance. Such machines sometimes have reactance as low as 2% or 3%. They operate in parallel very successfully and have very high synchronizing power when operating together in the same generating station. When an attempt is made to run such machines in multiple with some resistance between them, even only a few per cent., as by operating different generating stations together, hunting appears and parallel operation becomes an impossibility. That can easily be seen. Assuming we had some alternating current generators which had absolutely no internal reactance, but only armature resistance; such machines would have no synchronizing power whatever; that is, they would not keep together—would not even try to keep together—but when synchronized would simply drift apart. They would not even hunt, because hunting is an attempt to get together, and can appear only where there is some synchronizing power but not enough to keep them together against the tendencies which tend to push them apart. So without any reactance there would not even be hunting, but steady drifting apart. Synchronous operation requires that the reactance between the machines must be much higher than the resistance. Now while in the huge turbine alternator the reactance may be as low as 2%, the resistance is a fraction of 1% and therefore they still have perfect synchronizing power. But even if there were only

short lengths of cable between two power-houses at a moderate distance from each other, 2% or 3% of resistance, the internal reactance becomes not much greater than the resistance, and the synchronizing power practically vanishes. In such cases it becomes necessary to insert reactance at the synchronous machines, and when generators or generator, synchronous motor or converter, shall operate together over a circuit having some resistance, there always must be a reactance in the same circuit considerably greater than the resistance. In machines of very low reactance—or even in machines of considerable reactance where the resistance between them is large, as a high resistance feeder—the installation of synchronizing reactances becomes necessary for stability of operation. Such synchronizing reactances are being installed, and are a necessity to secure the operation of synchronous machines without hunting or drifting apart whenever the resistance between the two machines is not small compared with the reactance.

But it is not only synchronous machines which are unstable in their operation without reactance in their circuit, but there is an entirely different class of circuits which are unstable on constant potential supply. That is arcs. Arcs cannot be operated on constant voltage supply. Consider the arc as used in the arc lamp, which consumes about 70 volts. We could not operate such a 70 volt arc on a 70 volt supply system, whether alternating or direct. It would either go out or short-circuit. because it is inherent in the nature of the arc that with increase of current the arc voltage is decreased.

If, therefore, even momentarily the current would tend to increase in the arc, that would lower the voltage consumed by the arc. This would leave some surplus voltage, which therefore would increase the current; but increase of current still further lowers the arc voltage and causes still greater increase of current. So with increasing rapidity the current will rise to short circuit. Or, if the current momentarily begins to drop, that would raise the voltage consumed by the arc and the arc would require more voltage than available. With a constant voltage supply the current would decrease still further, but the more it decreases, the higher voltage is required and the more rapidly it decreases, until the arc goes out. So we see that stability of an arc requires in series with the arc a resistance or reactance consuming at least from 25% to 30% of the voltage. At the best, in operating the arc we cannot utilize more than 70% to 75% of the supplied voltage. When we look around at all existing arc circuits we always find that the arcs never utilize more than 70% to 75% of the available voltage of the circuit. Where it is a direct-current circuit, the remaining 25% to 30% has to be taken up by the resistance, representing a waste of power. If it is an alternating-current circuit, we can take up such re-

maining voltage by resistance or by reactance. In the latter case it means no consumption of power, but a lowering of the power factor. It means, then, if we consume by reactance the remaining 25% to 30% of voltage required to be consumed to give stability to the arc, the power factor is down to 70% to 75%. We find in every arc circuit, whether it is a multiple arc circuit or a series arc circuit, that we can never get a power factor exceeding 70% to 75%, except by replacing the reactance by resistance and lowering the efficiency by wasting the remaining 25% to 30% voltage in resistance instead of taking it up in reactance. In the ordinary arc lamp used on constant potential supply, each alternating arc lamp has its steadying reactance and operates at a power factor of 70% to 75%. On our series arc circuit, operating from a constant current transformer, all the necessary reactance is put together in the transformer; but the maximum output we can get from the transformer, the minimum reactance at full load, still is 70% to 75% power factor. Beyond that we cannot go, or the circuit gets unstable. So here we find another use of reactance—to give stability.

An entirely different use has been made and is still being made of reactances as protective devices, in protecting apparatus against disturbances coming in from lines, as lightning, arcing grounds, flash-overs, etc. There the reactance is acting as a barrier, keeping high voltage disturbances out of the station. The reactance is proportional to the frequency. A reactive coil may have a fairly low reactance—so low as not to have any appreciable effect on voltage regulation by consuming voltage at the normal frequency of the circuit, 25 cycles or 60 cycles; but if there appears on the line any high frequency disturbance, of 100,000 cycles or more, at this high frequency the reactive coil has an enormous reactance and so acts as a barrier. A reactance which normally at 25 cycles would consume 1-10% of the circuit voltage, would at 100,000 cycles consume 400% of the voltage; that would be a barrier through which the high frequency current could not pass to an appreciable extent. In this manner reactances have been used as "choke coils" at the entrance of lines into stations, to keep out high frequency disturbances which otherwise might enter into the station and there destroy apparatus. This use of reactance as a protective device against disturbance has been very extended but has, in the last few years, been to some extent discredited and less used. The reason is that there is some limitation to it, and like all apparatus it is only beneficial and useful when properly applied in the proper place, but cannot be used promiscuously, irrespective of whether it is right or wrong. We can easily see the limitation of the lightning protective reactance. First, it protects only at frequencies which are many times higher

than the normal circuit frequency, because its reactance must be low at normal circuit frequency—as 60 cycles, for instance. That means it will not offer a barrier against any disturbance of low frequency of a few hundred cycles, but only at very high frequency, many thousands or hundreds of thousands of cycles. It will be a very effective protection against the entrance of such high frequency voltages into the station. It then is a very high reactance, through which no appreciable high frequency current can flow. But there is a very important limitation in the design of such reactances. The reactance, to protect effectively, must have no appreciable capacity, because if there were any appreciable capacity of the turns of the reactive coil against each other, and if the frequency of the disturbance were high enough, it would go through, not by going around the turns of the reactive coils but by going across from turn to turn, through the capacity of the turns against each other. The individual turns of the coils, then, act like a series of condensers through which high frequency passes. Some designs of such protective reactances have been very inefficient in guarding against extremely high frequencies, especially, the design of a pancake coil of flat copper ribbon insulated with mica between the turns. The individual turns being flat against each other, give a high capacity. Besides mica has a very high specific capacity, four to six times that of air. With such a design, of a very high capacity, if the disturbance is of very high frequency, many millions of cycles, it passes through the reactance coil by static induction from turn to turn. So it will be seen that the protective reactance can protect only within a certain frequency range, a frequency sufficiently high so as to be many times higher than ordinary frequency, but not so high that it can go through by static induction, the capacity between the turns.

The most serious limitation of the protective reactance is, if it is a barrier against the entrance of disturbances from the line into the station, it also bars disturbances originating in the station from getting out and dissipating into the line. If there is a disturbance originating in the line, the protective reactance will keep it from going into the station, but if any disturbance originates in the station—for instance, in the transformer or by switching operations—then if there were no reactance, the line capacity would act as a short-circuit of the high frequency disturbance and make it harmless. Reactance acts as a barrier through which the disturbance cannot go, but reflects back and piles up in the station where it may destroy. So the reactance works both ways—as far as it does not let a disturbance into the station, it is good, but when it does not let a disturbance out of the station, it is bad. Thus the action of reactance as a protective device is that it protects those sections of the system

in which the disturbance does not originate, against outside disturbances, but increases the danger in that section where the disturbance originates. It protects the station against outside disturbances; it protects the line against disturbances in the station reaching the line; but it increases the danger of line disturbances, damaging the line insulation and increases the danger of station disturbances damaging station apparatus. The problem, then, is what part of the system is most likely to be the seat or origin of disturbances, and what part of the system is most valuable economically and requires protection most. If it is the same, then the reactance is dangerous, because it keeps the disturbance in where the danger is. If it is a different part; if the line—a 100,000 volt line—is insulated by insulators which could stand three or four or five times the normal voltages and which even a flash-over will not harm, and if the probability is that the trouble originates in the line, the station will be protected by reactance.

In other words, the reactive coil as a protective device is very useful, if properly installed and applied—if installed like any other engineering device, by an engineer knowing what he wants—but it has been rather dangerous when promiscuously installed anywhere and everywhere. That has somewhat discredited it and has caused engineers of recent years rather to fight shy of it—probably more than the occasion called for—and probably in many cases where it would increase the protection it was not used due to the discredit given it from those cases where it was not in its proper place.

In recent years reactances have found another application in the high power, huge generating systems to which the industry has now advanced—as here in Chicago, New York City, and elsewhere—where the station output measures by hundred thousand kilowatts; that is, we do not now measure power in kilowatts, but in megawatts. The industrial development of apparatus has, for reasons of economy of design, led by necessity to low reactance, much lower even than regulation demanded. That meant that we had generators of 2% or 3% reactance; transformers of 1% or 2%, power transmissions over underground cables which are of negligible reactance, so that there is hardly any reactance in the system. The resistance of generators and transformers is very low—a fraction of 1%. While the cables may have some resistance, this resistance also is very low. We cannot have much resistance drop in cables because resistance means energy consumption, converts power into heat, and this heat must pass through the heavy insulation of the high potential cable. Therefore, we cannot have much heat produced in the cable because the safety of the insulation does not permit it. So we have extremely small resistance and very small reactance. The means that any disturbance, any short-

circuit—inasmuch as there is such a terrific power—is dangerous, and liable to be very destructive in the entire system. It is practically impossible to design controlling devices, such as switches, which can be safely relied upon under all circumstances to open a short-circuit with such terrific power, amounting to many millions of kilovolt amperes, within reasonable size and cost. That means we must limit the power which can be concentrated at any point of the system by the introduction of power-limiting reactances; that is, by increasing the reactance of the system so as to give a reasonable limitation of power, to limit the current to ten or twelve times full load, which is bad enough, but well within the capacity of present day controlling devices. It means 8% to 10% reactance. Such a reactance may be in the apparatus or may be external to the apparatus. We may design the transformers with 5% to 8% or even 10% internal reactance, or we may design them with low reactance and add reactance externally. Originally the early transformers had 15% to 20% reactance, but that is not possible in a modern high-power transformer without a very great increase of size and cost. That means, then, we have the two alternatives: either to increase the size and cost of the apparatus to give it the high reactance, or add the reactance externally. Naturally the economical way would be simply to increase the internal reactance of transformer or generator to as high a value as can be given to it without serious increase of size and cost or material decrease of efficiency or margin of safety, and externally add the additional reactance required to give safety. It is an economical question which is preferable; whether the reactance should be provided internally by putting enough money in the transformer or generator, or externally by adding outside coils. Experience shows that in large transformers of even 25 cycles it is possible without serious increase of size or limitation of design to get from 4% to 6%, and 8% to 10% reactance appears perfectly safe. This means adding to the transformer 2% to 4% external reactance or increasing the internal reactance 2% to 4%. The latter can be done without serious increase of size. Usually economic considerations will show that it is cheaper to design the transformer a little larger, give it 6% to 8% internal reactance, than to give it only 4% reactance and add the rest outside. In most cases it is feasible, as far as protection is concerned, to give the transformers—without material handicap in design—sufficient internal resistance to be reasonably safe against such excessive power being concentrated by a short-circuit, at or beyond the transformer, as to endanger the transformer and the system by tearing the transformer to pieces by the mechanical forces of those currents or doing other damage.

Coming now to the generator, we find a different condition.

We can get, occasionally, 4% to 5% internal reactance, but to get still more internal reactance is very difficult. It increases the size, and cost, or lowers the efficiency. Usually it will be more economical to give the generator only a reasonable internal reactance and add the rest of the reactance as external reactive coils or in the form of step-up transformer or step-up auto-transformer, but not internal to the generator. Occasionally we hear and think and believe that it is easy to increase generator reactance; that increasing the number of turns on the armature makes a cheaper generator. In the old engine-driven alternators, we can readily see that if we increase the number of turns on the generator we increase the output and increase the size of the machine, but increase the output much more because doubling the number of turns on the armature would not double the size of the machine but would double the output. In this manner the higher armature reaction, and so the internal reactance, gives a cheaper machine, but if we continue to again double the reaction and double it again, we must come to the point where to accommodate twice as many conductors would require doubling the size of the machine. When we have passed this point then we may say that if we double the number of turns on the field, double the magnetic flux of the field poles, we double the output without doubling the size of the machine. So in a machine of low armature reaction, that is, of good regulation, we may get a cheaper machine by increasing the armature reaction. If we take a machine of very high armature-reaction and low field-excitation like a constant-current machine—as a Brush arc machine—there increasing the armature-reaction increases the size of the machine in the same proportion, but increasing the field magnetism cheapens the machine by increasing the output more than increasing the size. So we may see that the argument that we get a cheaper machine by increasing the armature-reaction applies only to those machines which were running with low armature-reaction. The reverse, that increasing the field—that is, relatively decreasing the armature-reaction—gives a cheaper machine, applies to those machines which had a very high armature reaction. Thus, if we increase the armature reactance in the low-reactance machines, finally we come to a maximum efficiency point—maximum economy point—where armature reaction and field excitation are proportioned so as to get the most economical machine. Increasing the armature reaction would make the machine less economical. Decreasing the armature reaction and so increasing the field would again make it less economical. When we come to the huge modern steam-turbine alternators, the old argument that we can get a smaller and cheaper machine by increasing the armature reaction does not apply. Increase as well as decrease of armature reaction makes a larger machine for the same size,

as we are at the maximum economy point of the relation between field and armature. Naturally not all machines are exactly at this point. Nothing is perfect. We can pick out many machines where we might get a little gain by increasing the armature reaction. In others, we might get a little gain by decreasing the armature reaction. In design we are also limited by the number of conductors which are feasible—which can be located properly—the number of slots, and by many other considerations. It is true that if we try to make a machine of as high armature reactance as possible, we can go a little beyond the maximum economy point towards high armature reactance, because at first we do not lose much, but if we go too far beyond that point we lose in economy. If the average machine has 3% armature reactance, we can go to 4% or even 5% without material loss in economy, but not to 8%. We can probably go still further by making certain changes in the design, but even there we soon strike a limit. Therefore, when we deal with generators of the high speed type, as steam turbine machines, it is more economical to get some of the power-limiting reactance as external reactance.

When we come to those huge machines running in parallel, the question of regulation is not material. With hundreds of thousands of kilowatts of generator capacity, ten thousand kilowatts is not appreciable in the regulation; so we do not need to consider regulation. Still there must be a limitation somewhere. We could not use a machine of 100% regulation, a machine where the short-circuit current does not exceed full load current, and where we have an increase of field excitation from no load to full load of 400% or more. Regarding regulation there is a marked difference between external reactance and internal reactance. Consider, for instance, a machine with 4% internal reactance. The reactance is not the only thing affecting the regulation, but in addition to the reactance we have an armature reaction which is much greater, which amounts to perhaps 20%. There is 4% true reactance of a total of 24% "synchronous reactance," which latter determines the regulation of the machine. Suppose we want to get 8% reactance. We add 4% external reactance. That means that instead of having 24% total we have 24% internal plus 4% external, or 28% total. That is, the regulation of the system is very little changed—in the proportion of 24 to 28. But suppose we get the additional 4% reactance by doubling the number of armature turns. That means double the internal reactance—from 4% to 8%—but it also doubles the armature reaction, from 20% to 40%, and now we get 40% armature reaction plus 8% reactance, or 48% total, which probably gives us an impracticably poor regulation. So far as reaction goes, we have made the regulation twice as bad as before by doubling

the internal reactance, but by inserting an external reactance we have made the regulation worse only in the proportion of 24 to 28 or about 15%. So we see in regard to its effect on regulation, external reactance has a very decided advantage over internal reactance. But naturally we cannot here go into this question in detail. Some of these things, as the effect of the power-limiting reactance and the synchronizing reactance, I discussed more fully in a paper before the Institute at the Chicago convention a few months ago.

Just one more point is to be considered, and that is in regard to the reactance as it exists in alternating-current circuits and even in direct-current circuits, where it usually is not appreciable because the current does not change except in starting and stopping. That is, the reactance is a representation of the electromotive force of self-induction. It is the effect of the electromotive force of self-induction—the electromotive force induced in the circuit by the magnetic field of the current in the circuit, which is represented by the ohmic apparent resistance which we call reactance. But go back for a moment to its cause, as a representation of the electromotive force due to the magnetic field of the current. The current in the conductor produces a magnetic field surrounding the conductor. This magnetic field represents stored energy, and wherever we have reactance in the circuit it means that we have energy stored in that circuit, in the magnetic field of the circuit. So we must never leave out of consideration that the reactive circuit contains stored energy, which has to be supplied in starting the current and which has to be returned to the circuit in stopping the current. And if we attempt to stop the current very rapidly, the more rapidly we stop the current the greater the rate at which the energy has to be returned to the circuit; that is, the higher is the electromotive force of self-induction. At a very high rate of stopping the flow of the current, if we attempt to break the current instantly, as occasionally occurs in an arc, we may get destructive voltages due to the very rapid dissipation or return of the stored energy of the magnetic field. So we must always consider the reactance as representing energy stored, just as a moving mass. A non-inductive circuit is related to a highly inductive circuit—a circuit containing high reactance—about the same as a light carriage to a heavy moving mass like a railway train. Both may go at the same speed, and still if you wish to stop the light carriage you can stop it almost instantly. If you attempt to stop the heavy railway train, going at the same slow speed, and you try to stop it at the rate at which you can safely stop the light carriage, it means its destruction, more or less, by its stored energy, its momentum. Those magnetic fields represent a momentum, a stored energy, which we have to keep in mind. Therefore, since every circuit

must have more or less reactance, and since safety requires it not to have too low reactance, it means that currents must not be ruptured instantly. That means that those types of switches which tend to open the circuit instantly at the maximum value of the current, like the air break switch, are dangerous in an electric circuit having an appreciable reactance. Those phenomena, like flaring arcs, which may under certain conditions cause a rupture of the current, are dangerous in those conditions where they rupture near maximum current. One of the main advantages of the modern oil switch is that it opens at zero current and therefore is free from this danger which was formidable with the air break type of switch. This storage of energy may appear as high voltage where an attempt is made to instantly rupture high currents with improper devices, that is, without waiting to the zero moment of the current wave where it is safe to open the circuit. But where there is energy stored in the circuit the energy may be stored in still another form, as, for instance, as electrostatic energy, in the capacity of cables and overhead lines, as transmission lines. Then there may be a transfer of stored energy from the stored energy of the magnetic field to the stored energy of the electrostatic field, and such a transfer may produce high or low frequency, depending on the condition of circuit.

There is a possibility of certain combinations of capacity and reactance which may lead to dangerously high voltages and all that. We have to consider that where there is a high reactance it means a high energy storage, and that means we have to guard against suddenly permitting stored energy to flow at too great a rate, at a destructive rate. It does not mean that we want to avoid reactance. That would be just as wrong as to say, let us make a railway car of a steam train as light as possible, run buggies instead of heavy Pullmans. We would get rid of momentum but we would not like to ride in such coaches. Safety requires heavy masses, requires momentum, and, in addition thereto, we must realize that we have stored energy and that we must not let loose the energy destructively but avoid this danger. We must know the danger to guard against it.

That is all I can think of to say regarding reactance as it affects the electric circuit. You see there is really only one objectionable effect. That is, where reactance is excessive it may impair the voltage regulation in a circuit containing only dead apparatus, like lamps and induction motors; but where we have synchronous devices, high reactance is beneficial in permitting voltage control.

Where we have synchronous apparatus, reactance is required to give stable operation.

Where we have arcs and similar conductors there we want reactance to give stability without waste of power. Resistance

would do the same, but it would represent loss of efficiency by consumed power.

Where we have concentration of energy in the huge systems, we want reactance to limit the possible destructiveness of power.

Where we have various circuits joined together as transmission lines, stations, cables, etc., reactance may be beneficial as a barrier to keep disturbances of some circuit section from entering and damaging other circuit sections.

All of these are beneficial uses except the first one,—and then where we have reactance we must realize that it is energy stored and control it, not let such stored energy run wild and damage.

DISCUSSION.

J. G. Wray, M. W. S. E. (Chairman): Gentlemen, I think you will all agree with me that we are exceedingly fortunate in being able to listen to Dr. Steinmetz' interesting and instructive lecture. I know that I voice the opinion of every one present when I say that we are deeply appreciative of Dr. Steinmetz' effort in coming out here each year. We have come to know this as the Steinmetz meeting. It is the only meeting of the year that we cannot hold in the Society rooms of the Western Society of Engineers, where our joint meetings are usually held, and we hope that Dr. Steinmetz will find it possible to continue these meetings in the future.

Dr. Steinmetz has told me that he will be willing to answer any questions that may be asked.

G. W. Cravens: Dr. Steinmetz spoke of the relation between resistance and reactance, that where resistance was any definite amount, reactance had to be greater for the sake of regulation. What is the rule as to the ratio?

Dr. Steinmetz: I think Mr. Wray did not quite represent me. I shall be glad to attempt to answer all questions, but I do not claim to be able to answer everything.

As regards the relation between resistance and reactance, we can vary it over a very wide range. If we make the reactance larger, then we require less lead and less lag of current to get the same control. The larger reactance we use comparative to the resistance, the less variation of phase is found to give the voltage regulation. Experience shows that, in general, if we go to a reactance less than twice the resistance, if the resistance is considerable, the amount of leading and lagging current is so great as to be objectionable in regard to the power factor and in regard to efficiency. And, if we come to too great reactance we find a limit of the current that can flow, and therewith a limit of the overload capacity of the apparatus, but the economical conditions are between two to four times the resistance. Where the resistance is low,—a

few per cent only,—we may go much higher in reactance. Where the resistance is considerable, we may have to stop at a reactance of not more than two to two and a half times the resistance; otherwise we may limit the power too much. But we can vary over considerable range and the fact of the matter is in railway transmissions where phase control is used, experience has shown that all practical cases can be covered by a constant reactance of between 15 and 18%,—2% to 3% in the transformer and 15% external. That may be coincident with the resistance of 2% or 3% or 5% or 10%. If the resistance gets too large, in such case we finally get to a point where the reactance is not sufficient to give perfect voltage control, and one gets either excessive current or he must sacrifice a little regulation. That is, the voltage does not remain perfectly constant, and will drop a little under load, but naturally very much less than it would without regulating reactance. Thus we can vary the reactance over a wide range, but it is undesirable to get to a range of less than twice the resistance, and we may say it is undesirable to go to a reactance of more than 40%, because then the power limitation becomes objectionable.

A Member: One question I would like to ask Dr. Steinmetz, and that is why iron cores are not used in external reactances more than they are.

Dr. Steinmetz: There is no objection to using iron cores, but it is uneconomical for this reason: The purpose of those power-limiting reactances is to limit the maximum current which can flow in case of short-circuit. Assume such a power-limiting reactance of 6%, which under normal current at normal load consumes 6% of the circuit voltage; that is one-sixteenth of the circuit voltage. If, then, a short-circuit occurs, the current at the short-circuit would be limited to sixteen times full load current. The reactance then would carry sixteen times full load current and would thereby consume the total current voltage; but in that case under short-circuit the magnetic flux of the reactance would be sixteen times what it is at full load. Now, the time when we want that use of the reactance is at short-circuit. Therefore, if we use an iron core we must design it so that at short-circuit, at sixteen times normal current, at sixteen times its normal magnetic density, it does not yet reach magnetic saturation. That means if we use an iron core we must run it at a very low density—say one-sixteenth of saturation—and probably about 1,000 lines per square centimeter, 6,000 lines per square inch. In such case the iron core would be so very large that the reactance would be, as a total, larger, and more expensive, and heavier than if air were used; because, where we use a density in iron of only 6,000 lines per square inch, 1,000 lines per square centimeter, we can get those densities very easily in air. So the absence of iron in those reactances is merely because they must not saturate under short-circuit, at say fifteen, sixteen, twenty, or more times their

normal density. So it is not that iron cannot be used, but merely that the use of iron is uneconomical, due to the extremely low density and the enormous size of iron core which would be required to keep the iron below saturation under short-circuit of the system. A different case is where we have the protective reactances, keeping out high frequency disturbances from the station, for instance. There iron is not permissible, because at these high frequencies eddy currents in the iron would be so large as to destroy the reactances. There one could use iron if he could laminate it so perfectly as to be fully effective at 100,000 cycles, as much as ordinary sheet iron is at 25 cycles. If we could get the iron in sheets as thin as less than one-tenth of a mil, we could use it in protective reactances. When we come to synchronizing reactances, giving stability to synchronous motor operation or to arcs, then we can use iron and do use it.

PROCEEDINGS OF THE SOCIETY.

MINUTES OF MEETINGS.

Extra Meeting, January 8, 1912.

An extra meeting (No. 768) of the Society, a meeting of the Bridge and Structural Section, was held Monday evening, January 8, 1912.

The meeting was called to order by Mr. John Brunner, Chairman, at 8:20 p. m. with about 35 members and guests in attendance. The minutes of the meeting of December 13, 1911, were read and approved.

A ballot was taken for the election of new members of the Executive Committee, and the following were elected:

F. E. Davidson, Chairman.

I. F. Stern, Vice-Chairman.

Wm. Artingstall and J. H. Prior, members of Executive Committee.

Mr. John Brunner, retiring Chairman, remains on the committee.

The amendment to the rules of the Bridge and Structural Section, presented by petition at the last preceding meeting, December 13, 1911, were voted on and adopted.

Mr. Ralph Modjeski was introduced who read his paper on the Celilo Bridge of the Oregon Trunk Line. This was illustrated by some interesting lantern-slide views.

Discussion followed from Messrs. I. F. Stern, E. Haupt, F. E. Davidson, R. G. Lawry, F. G. Vent, Ernest McCullough, and Mr. Modjeski.

The meeting adjourned at 9:35 p. m.

Annual Meeting, January 10, 1912.

The 42nd Annual Meeting of the Society (No. 769) was held Wednesday evening, January 10, 1912, in the College Hall, University Club Building, Chicago. The annual dinner preceded the meeting. The company of 129 convened about 7 p. m. for the dinner.

Seated at the speakers' table were President O. P. Chamberlain, President-elect W. C. Armstrong, the newly elected officers, First Vice-President A. Bement, Second Vice-President G. T. Seely, Treasurer, A. Reichmann, also Trustee W. W. Curtis, Dr. W. F. M. Goss, University of Illinois, Judge Marcus Kavanagh, of Chicago, and Lieut.-Col. George A. Zinn, U. S. Engineers, C. L. Strobel, Robert W. Hunt, W. H. Finley, and C. F. Loweth.

President Chamberlain called the meeting to order and after stating what had been planned by a special committee for the members and their friends in the way of an excursion on the following day to Pullman, Ill., and Gary, Ind., announced the award of the Chanute Medals for papers presented in 1910, found elsewhere in these Proceedings.

The Secretary presented an abstract of his annual report, and that of the Librarian. He also presented in abstract the annual report of the Treasurer

President Chamberlain then made his report, as is customary on retiring from the presidency, and in conclusion announced the result of the election and the names of the officers of the Society for 1912.

President-elect W. C. Armstrong was then introduced, who made a short address.

Dr. W. F. M. Goss was introduced, who read his paper on Citizenship, from the viewpoint of an educator. This was followed by an address from Judge Marcus Kavanagh on Citizenship from the viewpoint of a jurist.

The meeting then adjourned.

Excursions January 10 and 11, 1912.

The Special Entertainment Committee arranged two excursions for the members of the Society and their friends for January 10 and 11, 1912.

Through the courtesy of the International Harvester Co. and the C. B. & Q. R. R. Co., the party visited the McCormick Works Wednesday afternoon, January 10, returning in time for the annual dinner and meeting in the evening.

Through the courtesy of the I. C. R. R. Co., a special train was provided, which left Randolph Street station about 9:15 a. m. and conveyed the party of about 110 to Pullman, where they were met by representatives of the Pullman Company, who showed the visitors through the works. A train of Pullman cars of different designs and uses was provided by the company, which conveyed the visitors to different parts of the plant. Steel cars, for both passenger and freight service, under construction, were shown, as also many other points of interest in the company's plant. Soon after 12 o'clock the party were taken by the South Shore Electric Line to Ambridge Ave., near Gary, Ind., to the plant of the American Bridge Co. Lunch was served here by the American Bridge Co. and then the party visited the various shops and saw the work under construction. A special train on the L. S. & M. S. R. R. brought the visitors back to the city in time for the evening meeting (No. 770), when Mr. E. B. Frost, of the Yerkes Observatory, gave an illustrated lecture on "The Movement of the Fixed Stars," after which refreshments were served and the meeting adjourned about 10:30 p. m.

Extra Meeting, January 15, 1912.

An extra meeting the Society (No. 771), being the annual meeting of the Hydraulic, Sanitary, and Municipal Section, was held Monday evening, January 15, 1912. The meeting was called to order about 8:20 p. m. with Mr. L. K. Sherman presiding and about 30 members and guests in attendance. The minutes of the preceding meeting of the Section, held October 18, 1911, were not read but accepted as printed in the Journal.

A petition was presented and read by the Secretary as follows:

AMEND ARTICLE 1, by striking out the word "Corporate" in the last sentence and substituting "all grades of" so as to read: "Members of the Western Society of Engineers of all grades belonging to this section shall have the right to vote."

AMEND ARTICLE 5, by substituting the word "Monday" for "Wednesday," so as to read: "The regular meetings of the Hydraulic, Sanitary, and Municipal Section shall be held on the third Monday of October, January, and May, unless" (etc. as before).

AMEND ARTICLE 7, by omitting in the first sentence the words "nominated and" so as to read: "The Chairman, Vice-Chairman and two Directors shall be elected at the annual meeting."

ADD ARTICLE 7a as follows: "Nominations for officers of the Hydraulic, Sanitary, and Municipal Section shall be made in writing and filed with the Secretary on or before the third Monday in December. The names of the candidates shall be posted on the Bulletin Board in the Society's rooms."

The chairman announced it in order to nominate and elect officers of the section for the current year, a Chairman and a Vice-Chairman and two members of the Executive Committee, the fifth member of this committee being the retiring chairman.

The result of the election is:

C. B. Burdick, Chairman,
Langdon Pearse, Vice-Chairman,
C. C. Saner and
W. S. Shields as members of the committee.

Mr. Burdick then took the chair and Mr. L. K. Sherman read his paper on "Run Off from Sewered Areas." Discussion followed from Messrs. C. B. Burdick, Langdon Pearse, C. C. Saner, W. S. Shields, W. A. Shaw, and a closure from Mr. Sherman.

The meeting adjourned about 9:55 p. m.

J. H. Warder, Secretary.

ANNUAL REPORTS.

Secretary's Report.

Chicago, January 10, 1912.

To the Board of Direction, Western Society of Engineers.

Gentlemen: Of the affairs of the Society for the past year, 1911, I beg to report favorable progress in the accession of new members and in the meetings that have been held, almost weekly, except during July and August. Our rooms and library are being used more and more as our resources are increased, and become better known among our members and to the public. As our library is a free public reference library, it is resorted to frequently by those who are not members, but who are made welcome and are assisted in their searches for information as freely as though they were members. The Society is thereby filling its function in rendering aid in the dissemination of knowledge.

Applications for membership, or transfer of grade, filed in 1911, are somewhat more than in 1910, numbering 117, but of these there were 22 applications for transfer. The New Constitution, which went into effect with the beginning of the year, provided for additional grades of membership, and this led to some of the applications for transfer. The New Constitution also provided a new grade for students at engineering schools. There are three such now in our membership.

The total membership reported at the last Annual Meeting was 1,119, and now numbers 1,139, showing a net gain of 20.

Total membership December 31, 1910	1,119
Number of applications acted on, including some applications filed in 1910	142
Of which there were transfers of	29
Deduct losses by death, resignation and dropped	86
Failed to qualify	7
Total membership December 31, 1911	1,139

This membership of 1,139 is classified as follows:

	Resident.	*Non-Resident*	*Total.*
Honorary Members	1	2	3
Members	441	316	757
Associate Members	101	69	170
Junior Members	95	57	152
Affiliated Members	45	9	54
Student Members	2	1	3
Summary	695	454	1,139

During the year 1911 the Society has lost by death the following seven members:

H. A. Rust	February 5, 1911
A. D. Page	April 7, 1911
Wm. B. Ewing	April 8, 1911
J. N. Darling	April 22, 1911

Wm. Krames .... April 25, 1911
Adam Comstock .... August 16, 1911
W. D. Taylor .... August 26, 1911

During the year 1911 there have been 41 meetings as follows:

The Annual Meeting, January 11, 1911.
9 Regular Meetings.
1 Special Meeting.
30 Extra Meetings, which include certain social meetings, Ladies' Nights and Smokers.

But the attendance at these meetings is not uniformly as large as wished. The total attendance at all 41 meetings, including the very large attendance of over 450 at the Steinmetz Meeting, aggregated about 3,085, or an average of about 75 to a meeting.

List of Meetings Held in 1911.

January 11th. (No. 727.) Annual Meeting and Banquet held at La Salle Hotel, Chicago. Addresses from the retiring President, Mr. J. W. Alvord, and from the President-elect, Mr. O. P. Chamberlain, were made. Also there were addresses from Messrs. C. E. Merriam, G. C. Nimmons, W. H. Finley, and T. W. Snow.

January 18th. (No. 728.) Extra Meeting. Annual Meeting of the Bridge and Structural Section. A topical, informal discussion on the Handling and Working with Concrete in Freezing Weather.

January 25th. (No. 729.) Extra Meeting. Annual Meeting of the Electrical Section held jointly with the Chicago Section A. I. E. E. Prof. Morgan Brooks addressed the meeting on *Inductions from a Closed Circuit of the Globe.* Illustrated by lantern slides of his recent tour around the world.

January 30th. (No. 730.) Extra Meeting. Annual Meeting of the Hydraulic Sanitary, and Municipal Section. Mr. C. D. Hill addressed the meeting on the *Sewerage System of Chicago,* and Mr. Langdon Pearse addressed the meeting on the *Sewage Disposal Problem in the United States and Abroad.*

February 1st. (No. 731.) Regular Meeting. A. Bement presented the paper by John M. Ewen and himself on *The Public and the Public Service Corporation.*

February 8th. (No. 732.) Extra Meeting. A paper by A. S. Robinson, on *A Shuttle System for Chicago Subways,* was presented.

February 15th. (No. 733.) Extra Meeting. Paul P. Bird presented his paper on *Locomotive Smoke in Chicago.*

February 22d. (No. 734.) Extra Meeting. A Joint Meeting of the Electrical Section W. S. E. with the Chicago Section A. I. E. E. was addressed by Charles F. Burgess on *Electrolysis of Iron in Concrete.*

March 1st. (No. 735.) Regular Meeting. Raymond S. Blatchley, Geologist, presented his paper on *Oil Investigations in Illinois.*

March 8th. (No. 736.) Extra Meeting. Bridge and Structural Section. Josiah Gibson read his paper on *Cement Stock Houses.*

March 15th. (No. 737.) Extra Meeting. Dr. W. F. M. Goss read his paper on *The Illinois Engineering Experiment Station, in Its Relation to the Public.*

March 22d. (No. 738.) Special Meeting to receive a Report of the Committee on its investigation of the *State Geological Survey,* and the *Department of Mines* at the University of Illinois.

March 22d. (No. 739.) Extra Meeting. Joint Meeting of the Electrical Section and Chicago Section A. I. E. E. Caryl D. Haskins addressed the meeting on *Engineering and War.*

March 29th. (No. 740.) Extra Meeting and Smoker. Addresses made by President Chamberlain and Ernest McCullough on what the Society was doing and what was needed to be done to increase the value of the meetings and to promote greater sociability among the members. Wm. Artingstall gave an informal talk, with blackboard illustrations, of the new La Salle Street tunnel then in process of constructions.

April 5th. (No. 741.) Regular Meeting. James S. Stephens presented his paper on *Dynamics of the Flying Machine.* C. W. Morgan presented his paper on *Determination of Mean Radial Readings from Round Pattern Charts.*

April 12th. (No. 742.) Extra Meeting. George S. Rice presented his paper on the *Proposed Experimental Coal Mine of the U. S. Bureau of Mines.*

April 19th. (No. 743.) Extra Meeting, Hydraulic, Sanitary, and Municipal Section. John Ericson presented his paper on *Investigations of Flow in Brick Lined Conduits.*

April 26th. (No. 744.) Extra Meeting. Joint Meeting of the Electrical Section and Chicago Section A. I. E. E. A. C. Smith read his paper on *Electricity in Ice Plants.*

May 3d. (No. 745.) Regular Meeting. W. M. Wilson presented his paper on *Stresses in Guy Wires.*

May 10th. (No. 746.) Extra Meeting. Bridge and Structural Section. W. S. Marston presented his paper on *Storage Bins and Trestles at Cement Plants.*

May 17th. (No. 747.) Extra Meeting. Hydraulic, Sanitary, and Municipal Section. Prof. Gardner S. Williams addressed the meeting on *The Measurement of Water, Means Available, and Their Relative Accuracy.*

May 24th. (No. 748.) Extra Meeting. Joint Meeting of Electrical Section and Chicago Section A. I. E. E. S. G. McMeen presented some *Notes on a Telephone System Recently Built in San Francisco and Its Neighborhood.*

May 31st. (No. 749.) Extra Meeting. Ladies' Night. W. R. Patterson gave an informal illustrated lecture on his recent trip to the *West Indies and Across the Isthmus of Panama.*

June 7th. (No. 750.) Regular Meeting. Victor Windett presented his paper on *Foundation and Sewer Work—Costs and Comments.*

June 21st. (No. 751.) Extra Meeting. Ladies' Night. Wm. B. Leffingwell gave an illustrated lecture on *The Yosemite Valley.*

September 6th. (No. 752.) Regular meeting. W. C. Armstrong presented his paper on *The New Passenger Terminal of the C. & N. W. Ry. Co.*

September 13th. (No. 753.) Extra Meeting. H. Gansslen presented his paper on *Ball Bearings for Heavy Loads.*

September 20th. (No. 754.) Extra Meeting. J. A. Peabody read his paper on *The Signaling and Interlocking of the New Passenger Terminal, C. & N. W. Ry. Co.*

September 27th. (No. 755.) Extra Meeting. Joint Meeting of the Electrical Section and Chicago Section A. I. E. E. S. G. Neiler read his paper on *The Electrical and Mechanical Equipment of the New Passenger Terminal, C. & N. W. Ry. Co.*

October 4th. (No. 756.) Regular Meeting. Onward Bates addressed the Society on *Fundamentals.*

October 11th. (No. 757.) Extra Meeting. Bridge and Structural Section. Wm. Artingstall presented his paper on *The Chicago River Tunnels.*

October 18th. (No. 758.) Extra Meeting. Hydraulic, Sanitary, and Municipal Section. H. L. Cooper addressed the Society on the *Water Power Development of the Mississippi River at Keokuk, Iowa.*

October 25th. (No. 759.) Extra Meeting. Joint Meeting of the Electrical Section and Chicago Section A. I. E. E., held in Fullerton Hall, Art Institute. Dr. C. P. Steinmetz addressed the meeting on *Reactance in Alternating Current Circuits.*

November 8th. (No. 760.) Extra Meeting. Bridge and Structural Section. A. Reichmann read his paper on *Structural Steel Design.*

November 15th. (No. 761.) Postponed Regular Meeting. Judge J. C. Davis read his paper on *The Relation of the Railways as Common Carriers to the State and Federal Government.*

November 22d. (No. 762.) Extra Meeting. Joint Meeting of the Electrical Section and Chicago Section A. I. E. E. Frank F. Fowle read his paper on *Going Value.*

November 29th. (No. 763.) Extra Meeting. Ladies' Night. Wm. Hoskins gave an illustrated lecture on *Forms of Water-Snow Crystals.*

December 6th. (No. 764.) Regular Meeting. H. P. Boardman's paper on *Wind Pressure on Inclined Roofs* was presented by the Secretary.

December 13th. (No. 765.) Extra Meeting. Bridge and Structural Section. O. F. Dalstrom read his paper on *Shallow Floors for Railroad Bridges.*

December 20th. (No. 766.) Extra Meeting. Robert R. McCormick addressed the Society on *The Use of the Great Lakes.*

December 27th. (No. 767.) Extra Meeting. Joint Meeting of the Electrical Section and Chicago Section A. I. E. E. James Lyman presented his paper on *Protection of High Tension Power Circuits and Apparatus.*

In accordance with instructions from the Board of Direction, we have published our Journal this past year as a monthly except for July and August. This seems to meet the approval of our members, but it has very greatly increased the labor of publication. Strenuous efforts have been made (and generally successful) to issue the Journal in the latter part of each month. The December issue is a very large and heavy number—over 200 pages—and is about two weeks behind time. The Journal for 1910 contained 846 pages in the six issues. For 1911, with ten issues, there are 1,140 pages. This does not include the advertising.

The active co-operation of all of our members is earnestly solicited for the pushing forward of our Journal. With a membership of over 1,100, there should always be at least a few good engineering papers in the hands of the Secretary awaiting their turn for printing and presentation. Our membership can render the Society no greater assistance than by preparing and forwarding to the Secretary papers of engineering interest for the consideration of the Publication Committee. The assistance from membership is also solicited in advertising the Journal and soliciting subscriptions from those engineers and technicians who are not members of the Society.

Respectfully submitted,

J. H. Warder, Secretary.

Librarian's Report.

Chicago, January 10, 1912.

To the Board of Direction, Western Society of Engineers.

Gentlemen: The Librarian begs to submit the following report on the library of the Society, for 1911:

Total accession list at the end of 1911 8,421

Additions to the library during 1911 are classified as follows:

Number of bound books—gifts and exchanges	474
Number of volumes bound by the Society	84
Number of volumes purchased	48
	606

Total charges against the Library Account, classified as follows:

Bookbinding	$162.05
Book purchases	140.10
Services in the library	85.55
	$387.70

In addition to the preceding, there has been charged to the Furniture and Fixtures Account, $109.00, expended for bookcases, addressing machine, and typewriter desk.

Very respectfully submitted.

J. H. Warder, Librarian.

Treasurer's Report for the Year Ending December 31, 1911.

January 3, 1912.

To the Board of Direction, Western Society of Engineers, Chicago, Ill.

I respectfully submit herewith a statement of the Treasurer's account for the year ending December 31, 1911, as follows:

CASH STATEMENT.

January 1, 1911, cash in bank, subject to check		$ 859.69

RECEIPTS.

Dues	$12,496.03	
Entrance Fees	1,053.00	
Subscription to Journal	281.07	
Advertising	2,972.69	
Sales Journal	92.90	
Interest	673.66	
Journal Account	105.15	
Library Account	55.65	
House Expense	611.56	
Stationary, Postage and Exchange	62.55	
General Printing	204.80	
Chanute Medal Fund	25.00	
Bound Journal	83.30	
Medal Account	25.00	
		18,742.36
		$19,602.05

EXPENDITURES.

Entrance Fees	$ 10.00
Journal Account	6,420.46
Library Account	298.40
House Expense	5,372.35
Stationary, Postage and Exchange	1,044.12
General Printing	1,502.39
Furniture and Fixtures	109.00
Bound Journal	16.37
Bills Payable	1,008.33
Services	1,950.00
Medal Account	27.00

Library Services	85.55	
		$17,843.97
December 31, 1911, cash in bank subject to check		1,758.08
		$19,602.05

SUMMARY.

Statement January 1, 1911:

To credit of Western Society of Engineers	$ 7,309.59	
Chanute Medal Fund	1,274.00	
Arnold Fund	1,000.00	
		$ 9,583.59
Investments	9,723.90	
Cash	859.69	
	$10,583.59	
J. H. Warder's note	1,000.00	
		$ 9,583.59

Statement January 1, 1912:

To credit of Western Society of Engineers	$ 9,182.08	
Chanute Medal Fund	1,299.00	
Arnold Fund	1,000.00	
		$11,481.08
Investments	9,723.00	
Cash	1,758.08	
		$11,481.08

Respectfully yours,

ALBERT REICHMANN, Treasurer.

REPORT OF THE JUDGES OF ELECTION.

The undersigned Judges of Election, having canvassed the ballots cast for officers of the Western Society of Engineers for the year 1912, have the honor to report as follows:

Total number of votes cast	375
Number of ballots rejected as irregular	6
Number rejected as not qualified to vote on account of non-payment of dues	1
Number of ballots counted	368
Number of votes cast for President:	
W. C. Armstrong	360
Number of votes cast for First Vice-President:	
A. Bement	196
C. R. Dart	162
Number of votes cast for Second Vice-President:	
G. T. Seely	356
Number of votes cast for Third Vice-President:	
E. C. Shankland	358
Number of votes cast for Treasurer:	
A. Reichmann	356
Number of votes cast for Trustee for three years:	
J. G. Giaver	121
B. E. Grant	111
L. K. Sherman	118
Scattering votes	1

Respectfully submitted,

EDWIN HANCOCK,
RUDOLPH G. ROSENBACH,
CHAS. STEWART,
Judges of Election.

January, 1912

REPORT OF COMMITTEE ON AWARD OF CHANUTE MEDALS.

Your committee appointed to consider the papers read before the Western Society of Engineers during the year 1910, and to recommend which of these papers should be awarded the Chanute medals, has completed its work, and begs to report as follows:

It is recommended that the Chanute medal for the best paper in Civil Engineering be awarded to Charles K. Mohler for his paper entitled "Earth Pressures," read before the Society April 6, 1910.

It is recommended that the Chanute medal for the best paper in Mechanical Engineering be awarded to C. P. Berg for his paper entitled "Heat Treatment of High Speed Tools," read before the Society June 15, 1910.

It is recommended that the Chanute medal for the best paper in Electrical Engineering be awarded to H. B. Gear for his paper entitled "Diversity Factor in the Distribution of Electric Light and Power," read before the Electrical Section March 23, 1910.

The committee eliminated from the papers presented during the year one committee report and two papers by non-members whose applications for membership were dated subsequent to the presentation of their respective papers.

(Signed)
W. L. Abbott,
J. R. Cravath,
C. F. Loweth,
Committee.

ADDRESSES AT ANNUAL DINNER.

Address of Retiring President, Mr. O. P. Chamberlain.

This day marks the completion of the first year's work of this organization under our new constitution.

The reports that have been received show that the material changes—I might almost say radical changes—made in our organization in accordance with that document have been successfully accomplished.

That these changes could be made without some friction was not to have been expected. But we are glad to know that the difficulties incident to them have, through the tact and diplomacy of our Board of Direction, been quite generally surmounted; that the rough ways have been made plain and the crooked paths straight; that we are comfortably habituated to our new rooftree. The hearth is warm and the latch-string is out, and we are ready to bid welcome, good cheer, and Happy New Year to all worthy members of the engineers' brotherhood.

While we cannot, perhaps, point to nineteen hundred and eleven as a "banner year" for our organization, we feel that, at any rate, we have not retrograded. We enter upon our second year of life and endeavor under this constitution, with a sound financial status, an increased membership, an efficient board of officers, and with a firm determination to continue in the path of progress, prosperity, and efficiency.

Another innovation of the year that is past was the changing of our Journal from a bi-monthly to a monthly publication. The occasion for this change, as was explained a year ago, was the increase in the number of desirable papers presented, due to the creation and activities of the Electrical, Bridge and Structural, and Hydraulic, Sanitary, and Municipal Sections. The success and excellence of the monthly publication has justified the additional labor and expense which the change necessitated.

The President, on behalf of the Society as well as on his own behalf, thanks his colleagues and especially the members of the Board of Direction, for their faithfulness and devotion; for the many precious hours they have snatched from their vocations to devote to the advancement and upbuilding of the interests of the Western Society of Engineers.

It is a custom of this Society, sanctioned, I am told, by long-established precedent, that the retiring President, whether he speak with the tongues of men and of angels, or whether he be deaf and dumb, shall on the occasion of the "annual meeting" rise on his feet before the guests and members there assembled and attempt a farewell address which, I take it, is a sort of official swan song.

I thought the new constitution might have something to say about the farewell address; so I got out my copy, which I had perused more or less diligently during the past year, and looked it over. I could find nothing there, pro or con.

The last winter I lived in my native state of New York, when I was a half-grown boy, an incident occurred which, as some of those little affairs of childhood will, has always remained in my memory. We used to coast down a steep paved street called Lincoln Street Hill. That winter, after the snow had become thoroughly packed, there came a January thaw and rain, followed by a hard freeze, and Lincoln Street Hill, as well as the other paved streets, became a glare of ice. We used to do most of our coasting on what we called double-deckers—two sleds fastened tandem, with a top board, and carrying anywhere from four to ten children, each. I didn't happen to be on the hill the night after this freeze, but what happened was that a few trips were made down the hill. On account of the smoothness of the ice, and the crown of the street, the sleds were unmanageable and slid into the curb while going at high speed down hill; a number of children were hurt, and after the first few minutes of coasting the police department interfered, stopped the sport and cleared the hill. Now there was nothing remarkable about the incident itself, certainly nothing funny—quite the reverse. But one of my classmates, in telling me next morning of the evening's adventure of the boys, wound up his narrative in all seriousness with these words: "And three of them were knocked sensible." Knocked sensible! Those two words have remained all these years somewhere in a cranny of my memory to pop out at the most inopportune times. On how many occasions I have wished it could be done.

As I turned the pages of the constitution, those two words came back—"knocked sensible." Why hadn't there been a way by which the committee that revised the constitution could have been "knocked sensible" and inserted a clause forbiding us fellows from making addresses who have attempted nothing in the way of oratory since we recited those bits of bombast, "Cataline's Defiance," "Rienzi's Address to the Romans," and "Sparticus to the Gladiators" in the old school-house a generation ago?

However, as the preparations for the annual dinner progressed, I found the members of the Board of Direction were taking it for granted that the retiring President should deliver an address, and they made up the program that way.

Some of them hinted more or less tactfully that an address without poetry would be preferred.

Now I can conceive a swan song without words. In fact, it seems to me I have heard or seen somewhere classic human songs without words. But to produce a song with words and without poetry. Now, how could I?

One of the members suggested that I make the address all jokes. I assured him the entire matter was no joke to me. It was serious and I intended to attack it in a serious manner. My profession has been a serious thing to me. I have never wished I had become a clergyman, a doctor, a lawyer, a butcher, a baker, or candlestick maker; always glad I was an engineer. Thus far that has been my life—engineering, mixed more or less with business—and perhaps because of that last fact more than any other, I am treating this subject in all seriousness as I do.

Much has been said and written of the ethics of the engineering profession—some things good, some indifferent, some foolish. We will assume that all are agreed that truth and fidelity constitute the summation of our

ethical code, and now briefly discuss the relation that the engineer does bear and should bear to business.

The word "commercialism" like the word "politics" has in these latter days acquired in many minds a false and sinister meaning. So that when a man is spoken of as being inclined to—I was almost on the point of saying guilty of—commercialism, just as when a man is spoken of as being interested in politics, the thought of dishonesty at once flashes through the mind of the hearer. Why? Because business—more particularly what is popularly called "big business"—as well as politics, both big and small, have not been organized and conducted on the planes of truth and fidelity. Yet every engineer, in fact every man, must to a certain degree interest himself in the commercial side of his vocation, and every man must in his own particular sphere be something of a politician if he expects to be successful. From that statement should be excluded, perhaps, tramps and loafers both of low and high degree.

Speaking of tramps reminds me of a story. A hobo was wending his weary way through a village when he chanced to stop at the door of an old deaconess who, though wishing to be charitable, was inclined to couple her charity with economy. He asked for food and was given a piece of bread. While he was casting his eyes over the bread, which was dry and unpalatable looking, the woman said: "My good man I don't give you this bread for your own sake, but for God's sake." The tramp quickly returned the bread with the rejoinder: "For Christ's sake, mum, put some butter on it." We must admit that his class has little to do either with commercialism or politics. Look at the reason for your own professional being. Doesn't commercialism stand back of it all? You are the chief engineer of a great transcontinental railway. You are working fourteen hours a day and lying awake nights to devise schemes to reduce cost of construction and maintenance so that your company may secure a larger margin of profit in selling its transportation of passengers, merchandise, and farm products. Commercialism! You are an architect. While you are perhaps most interested in the artistic features of that great office building you are designing, you must give your attention to economic construction and prepare plans of a building that will earn for your client a fair return on the money invested. Commercialism! You are a mechanical engineer. You devote your best thought and experience to constructing, let us say, a bolt machine that will produce steel bolts a little better and a little cheaper than has been done heretofore, that your company or your client and incidentally you, yourself, may profit thereby. There is commercialism again. Take any engineering illustration you choose and follow its reason for being far enough down the line, and you will find the origin commercial.

To paraphrase a line of our own and only George Washington Cohan: "Engineering's a commercial proposition after all."

We are living in an era of production on a tremendous scale, of companies with enormous capitalization, large output, scientific methods of manufacture and consequent economic production and low cost. There is nothing dishonest and revolutionary in this. On the contrary, it is honest and evolutionary, and all the legislatures of all the states and the Congress of the United States with their drastic state corporation laws, their Elkins laws, and their Sherman laws can only check, not stop, this evolution.

Incidentally, the strange thing is that in all the corporation laws passed, the one dishonest thing that has brought about these restrictive laws that has placed a stigma on the word "commercialism" and made the people anathematize trusts and corporations has never been touched. I refer to the wholesale watering of stocks or the issuing of securities behind which are no tangible assets.

Now, under these conditions, in this great age of industrial evolution, more than ever before, business, and particularly large manufacturing corporations, need engineers, not only in the drafting room, in the design and construction of buildings, railroads, and machinery, but in the higher execu-

tive positions where executive ability is reinforced by technical skill and experience in the direction of large affairs.

I shall never forget a saying of an old bridge supervisor employed on the railroad where I acquired my early engineering experience—an exceedingly competent practical man, by the way. He would say, after finding a mistake in grade stakes given him, or some similar error: "If God Almighty had been an engineer, the world would have never been built." And he was not alone in his feeling of contempt for the technical man.

Today, with a few notable exceptions, the prejudice among the directors of large affairs against the engineer has passed, because the engineer has "made good."

Now isn't an executive position a perfectly fair, legitimate aim for any engineer, provided he has developed executive ability?

There are some brilliant technical men who have deservedly risen high in the engineering profession to whom, no doubt, an executive position does not appeal. But men are differently constituted. We are not all qualified for a consulting practice. Should we all attempt it most of us would probably soon hit the bread line, and to many engineers the broadening out into executive position, should they be fitted for them, will undoubtedly be a benefit to the corporation employing them, besides perhaps making their own lives longer and happier in their increased and diversified activities.

A messenger boy who rode a bicycle frequently traversed the same narrow road taken by an undertaker's assistant who drove a handsome black van-like automobile. The chauffeur incurred, or at least promoted, the dislike of the messenger boy by running up behind him so that the boy must stop and stand aside in the ditch or be run down by the machine. One day the boy determined on retaliatory action. Before starting on his trip he secured a piece of sheet iron with a rough edge. As usual the chauffeur tried to run him down, and as usual the messenger jumped from the wheel and stood close to the ditch. As the auto passed, however, he whipped out the rough iron and pressed it against the shining side of the van, scoring the paint and varnish from end to end of the vehicle. He then jumped on his bicycle and started back in the direction whence he had come, throwing over his shoulder the taunt: "Every time you try to get me, I'll scratch your automobile." As the story goes, he was not molested again. So with some of us, while we cannot eventually escape the undertaker, we may, by sufficiently diversified activity, retard him; we may check him; we may scratch his automobile.

In the opinion of Guido Sacerdote, an Italian mechanical engineer whose experience embraces practice in both Europe and the United States, the American mechanical engineer has not fully come into his own, so far as executive positions are concerned, though he admits the desirability of engineering executives in large manufacturing concerns and states that such is the European practice. Among other things he says:

"Instead of allowing the men who are responsible for our engineering and industrial successes to manage our great concerns with a free hand, we are making them bondsmen of the bookkeeper and the salesman."

Mr. Sacerdote takes a rather pessimistic view of the matter.

In many of our large industrial corporations, and particularly on some of our great railroads, had he investigated carefully, he would have found the highest executive positions occupied by engineers. In order to present the matter from his viewpoint, however, I wish to quote a little further. He says:

"In what capacity is the engineer employed in America? Aside from those who have means, opportunity, and ability to start independently as consulting engineers, those employed in factories and industrial enterprises are really confronted by very poor prospects. Not every one can be a consulting engineer. The others should not be generally restricted to drawing-room duties. Still, such is the case here."

One other quotation. Speaking of the factory practice in Europe, Mr. Sacerdote says:

"The engineer passes judgment on things: the engineer holds a position morally very high; his opinion is sought and respected; he occupies the place that he really deserves in the industrial world, as well as in the social world.

"American manufacturers can not fail to realize that competition is becoming more and more keen; that very soon common sense and practical knowledge alone will not suffice. It is to be hoped, if not in homage to justice, at least through the necessity of industry, that the American engineering profession will rise to a higher plane. At the same time the engineers must help themselves."

In the last two sentences, granting that we are behind Europe in the placing of engineers in executive positions, though perhaps not so seriously delinquent as the author just quoted believes, he strikes the keynote when he speaks of the "necessity of industry."

The "necessity of industry" is the moving force in the industrial evolution now taking place, of which I have previously spoken, and in that evolution the engineer is bound to advance in the general progression and come more fully into his own.

Mr. Sacerdote's statement, that "the engineers must help themselves" might well be emphasized and individualized by this supplement: "and each engineer must help himself." No one thing is of greater assistance to an engineer, provided he has mastered a problem, besides his ability to work independently, than the tact and address which will convince his superior that when he, the engineer, states anything, he knows it and he knows he knows it. Next to his knowledge and experience, the courage to stand alone and independent when honesty and fidelity require, is the most valuable asset of the engineer.

In closing, there come to me a few lines written by one of our American authors, that I read years ago. Though I have not re-read them for many, many years, I have often thought of them as applying with especial force to the engineer. That there is more of truth than poetry in them, must be my apology to those who have tabooed poetry in this address.

"There's a game much in fashion—I think it's called euchre,
Though I've never played it, for pleasure or lucre—
In which, when the cards are in certain conditions,
The players appear to have changed their positions,
And one of them cries, in a confident tone,
I think I might venture to 'Go it alone.'

"While watching the game, 'tis a whim of the bards,
A moral to draw from the skirmish in cards,
And fancy, he sees in the trivial strife
Some excellent hints for the battle of life,
Where, whether the prize be a ribbon or throne,
The winner is he, who can 'Go it alone.'

* * *

"In the struggle for power, or scramble for pelf,
Let this be your motto, 'Rely on yourself,'
Then, whether the prize be a ribbon or throne,
The victor is he who can 'Go it alone.'"

Section 13 of Article VII of the constitution reads: "At the Annual Meeting the President shall announce the result of the election, and the officers-elect shall assume their duties immediately upon such announcement." Immediately. That means instantly—at once. If I had made that announcement earlier than this, the new President, who is a bigger man than I am,

would have kicked me right out of this chair and not permitted me to speak at all.

Before I make this announcement, however, I will tell a little story:

Mirandy was a big, able-bodied colored woman, who lived in a small mill town, and for a livelihood washed and ironed clothes. Rastus, a shiftless little colored fellow, who worked more or less regularly in the mill, kept company with Mirandy, calling at her home not less than three evenings a week and escorting her to all the social affairs of the colored people.

A few weeks ago Rastus got to dropping around occasionally on an afternoon, and in reply to Mirandy's queries why he wasn't working, invariably replied: "Mill shut down. Short time today."

On one of these afternoons after fidgetting about on the back step for a time, Rastus began to turn the wringer for Mirandy.

Between spells of wringing, Rastus kept up a desultory conversation that terminated about as follows:

"Mirandy, you certainly done got powerful fine arms."

"Ach huh."

"'Pears to me I never did see such a fine washer as you be."

"Uh huh."

"'Spects you beat dis town fo' washin'."

"Uh huh." Mirandy was too busy to talk much, but she was thinking constantly.

"Mirandy, we done bin keepin' comp'ny a right smart time. What yo' say, we go down to de parson's dis ebenin' and get married?"

Mirandy drew her hands slowly out of the suds, wiping them on her apron. Then placing a hand on each hip and turning to her dusky lover, screamed: "Rastus, yo' done lost yo' job."

Gentlemen, I have lost my job.

The result of the election canvassed by the Board of Direction on Friday, January 5, 1912, is as follows:

President—W. C. Armstrong.

First Vice-President—A. Bement.

Second Vice-President—G. T. Seely.

Third Vice-President—E. C. Shankland.

Treasurer—A. Reichmann.

Trustee for three years—J. G. Giaver.

In introducing our new President, I want to state that he originally had opposition, but succeeded in dispersing it before the ballots were taken. His running reminds me of that of a colored slave, as told by himself, in his escape from the patrol, or, as he called them, "Paterollers," after he had run away from the plantation. He told it something like this:

"I'se a runnin' down de 'pike jes' easy when I hear de horses comin'. I know dat dose paterollers comin'. So I run faster twell I come to a cornfield. Den I turns and runs down de corn rows. I hear dose paterollers still comin' and I run, an I run fas'er and fas'er twell I see little cottontail runnin' jus' ahead o' me and I run fas'er an fas'er when I hear dem paterollers, twell I trip on dat cottontail. Den I say kin' a soft like: 'Shoo,' but he don' shoo, an' I stumbles over him 'gain. Den I sho' am mad an' I give him a side kick over inter nex' corn row, an' I say: 'Get out mah way you fool rabbit an' let somebody run dat kin run."

Seriously, gentlemen, he was unopposed because of his admitted fitness for the position, and because we all knew he would be elected anyway. It gives me great pleasure to introduce our President, Mr. W. C. Armstrong.

Mr. W. C. Armstrong, President-elect: Members of the Western Society: An assemblage of this kind, after having partaken of such a dinner, might be considered to be in a sort of a non-resistive condition; and if I felt so disposed I might take advantage of that condition and perpetrate an address upon you, as I see, according to the program, I am expected to make an address. But I assure you that my intentions are more considerate.

I have no set speech to make. Custom has not imposed upon the incoming President the duty of making an address. He is only expected to make his bow. But custom has laid that duty quite rigidly upon the retiring President; it is expected of him; he cannot get away from it. We expect him to make a review of the year's work, to embellish his remarks with such oratory as he pleases, to shed wisdom and advice and all those things, for he can do those things with impunity; he has nothing to fear. He is passing beyond the reach of criticism. He is entering into that exalted class of immortals whose names are perpetually printed in capital letters in the Year Book and who most useful in ornamenting the Speaker's table at the annual dinners. An incoming officer in any organization should be careful in expressing any preconceived ideas, just as a candidate should be careful in expressing any pre-election promises, because he might, perchance, be brought to the condition where he would be compelled to recognize them, and that would be very embarrassing.

I desire particularly on this occasion to express my deep sense of gratitude for, and my appreciation of the honor that you have conferred upon me. I feel that it means something to belong to the Western Society of Engineers, and I feel that it means a great deal more to be honored with the highest office in the gift of that organization. I feel that it is a trust and a confidence that can only be repaid by loyalty and devotion to the best interests of this Society. I hope that that confidence will be justified by my loyalty.

A technical society like the Western Society of Engineers, or any organization of professional men organized for the purpose of improving the profession and the spread of knowledge in their particular line, does not accomplish its greatest result nor the full measure of its possibilities in advancing that science alone for which it was organized and for which it stands. There is a broader field of work for every such organization. An engineering society should endeavor not only to increase engineering knowledge, and place that knowledge within reach of all of its members, but should have for its object the widening and spreading of that knowledge over the entire world for the benefit of mankind generally. It should not only aim to create and promote better engineers, but better men, broader men, men capable of bringing a higher degree of intelligence into the solution of the many social, political, industrial and economic questions that are pressing forward for solution. In fact, its aim should be to promote a class of men with the highest conceptions of man's duty and obligation as a citizen.

We hear a good deal said about citizenship. There are a great many social, economical and industrial questions that can only be properly solved by a higher type of citizenship; by a higher conception of citizenship. I think you will all agree with me that we are passing through a sort of transition period as respects industrial conditions. The old order is passing away and we have not yet adjusted ourselves to the new order. A great many questions are yet to be decided, and these will call for the highest type of intelligence, the highest type of citizens. So important is this question considered that we have decided to turn our thoughts for the rest of this evening upon that subject of citizenship, and we are fortunate to have with us two men whose professional standing and experiences in life are such as to eminently qualify them to speak to us on that subject. The first of these will be Dr. W. F. M. Goss, Dean of the Engineering School at the University of Illinois. He will speak to us upon the subject of "Citizenship" from the viewpoint of the educator. Dr. Goss.

Dr. W. F. M. Goss, ASSOC. W. S. E.: Citizenship has a two-fold aspect; it associates the individual with all the people of his community in a manner which secures for him the rights and privileges which others enjoy, and it imposes upon him certain responsibilities toward society. In its original meaning the term expressed an affiliation which was local, and while in more modern times the benefits conferred upon the citizen have increased and

we have widened our interpretation, it cannot be said that our provincial conceptions of citizenship have entirely disappeared. For example, it has been remarked—jocosely of course—that certain people of New England do not yet fully understand that they are fellow-citizens with those of us who live in the middle west. It is said to be sufficient for them that their citizenship is derived from Boston.

We are all more or less inclined to give a local hue to our citizenship, but such distinctions are the result of superficial coloring due to environment. They are not distinctions involving differences in quality, for in the large, our citizenship is based upon conceptions of truth and upon right dealing, and these are matters which cannot be localized. The citizen, whether of the east or of the west, whether rich or poor, is secure in the possession of property and in the pursuit of his chosen activities in so far as what he has and what he does are based upon right action. This nation-wide security helps to make up our national citizenship. We are identified with the people of a great nation, and we know that wherever we go the flag will follow and protect us. But from an international point of view we are all in danger of being provincial in the estimate we place on citizenship. We think of ourselves, of our interests and our power to maintain our way, and we count our neighbors as less favored than ourselves. We forget that just what the United States is doing for the protection of its citizens, other enlightened nations are doing for the protection of their citizens, and that the whole civilized world is much the same in its spirit of citizenship. Why not broaden our sympathies and look beyond the borders of America to the possibility of an international citizenship, a citizenship through which every civilized nation guarantees every individual, regardless of his birthplace and regardless of his creed, the right of life, liberty, and the pursuit of happiness; a citizenship which if established would mean international peace.

Booker T. Washington has said that in winning the esteem of the whites, colored men must have possession of something which white men want. The colored brick maker who finds his customers among the white planters does not need to raise the question of his social standing with his neighbors. The mere fact that there is trade between them establishes a good understanding and dignifies the parties in interest. That which is true in the development of workable relations between the blacks and the whites in the south is true in principle the world over. Intercommunication among people and the exchange of commodities between them have had their effect everywhere in enlarging the sympathies of mankind. The means for the exercise of these functions have been given by the engineer. He has built highways and railroads over which men may easily travel and transport their goods. His factories are busy with the manufacture of articles which all people want. His coals, ores and metals, his machine tools, his pianos, and his automobiles are the currency with which we cultivate the friendly relation of our neighbors and of nations. The easier and the more rapidly we may travel, the greater and the more productive our factories, the more skilfully we develop and utilize our national resources; in short, the greater the activities and efficiencies of our engineering undertakings, the more rapidly this community, our nation, and all the nations will advance their standards of citizenship. In its ultimate analysis the world peace movement is a business and an engineering proposition.

The individual's responsibility toward his citizenship is a matter of the highest importance. Through his citizenship he has his heritage among the people of a great nation. What should he pay? First of all we will agree that he should cultivate in himself and in others a spirit of appreciation for his citizenship; not merely that spirit which stimulates praise when the trend of national legislation is to our liking, but a spirit of appreciation which under adverse conditions impels one to prize his privileges and which makes him ready even to fight for his citizenship, a spirit of loyalty which lifts one up above the turmoil of routine to a vantage point from which dis-

turbing factors may be seen as merely things of the day, which impels one to guard his own character that he may be the more worthy to discharge the duties which his citizenship imposes and which makes him ready to pay for his citizenship in the coin of every-day service to society. In the program of the day the service of citizenship must come first. No routine call of the office or demand from the field or factory is likely to be more important than the call of the state on election day and the reasonable expectations of society all other days. The last year has afforded me a remarkable manifestation of the extent to which this conception is accepted by the engineering profession. When matters affecting vitally the future usefulness of the University of Illinois, an institution of the state and for the state, were under public discussion, the members of the Western Society of Engineers rose almost as a man and asked, "What can we do?" Many who were doubtless busy enough without it, joined with other engineers and citizens of the state in a campaign which amounted to a popular uprising on behalf of higher ideals in education. The result was a most significant one. A step was taken by the Legislature, which provides for a more permanent basis of support and for the increased support of the University. Let me in this presence say that in my opinion few acts of citizenship were ever inspired by purer motives or have resulted in a greater public service than those which were performed last winter by the members of this Society for the upbuilding of a College of Engineering at the State University.

It is exceedingly fitting that engineers as a class should guard their citizenship with jealous care. Their calling is in a peculiar sense one of public service, and their work tends to instill within them the highest qualities of character. While his work constitutes the most remarkable service which has been rendered society in modern times, it is not infrequently asserted that with reference to certain details of citizenship the engineer is more likely to fail than the lawyer or the preacher. I am not prepared to say that this is true, but we must recognize certain tendencies in his training and practice which tempt him to ignore some of the more common claims of society. It is unfortunate that in the training of engineers, whether their rise be through the channels of practical experience or through the college, there is a tradition that the candidate must submit to hard knocks and to work of drudgery, not merely that through these an approach to avenues of useful information may be gained, but on the theory that hard knocks and drudgery are themselves influences which develop. Far be it from me to preach a gospel of ease. Whatever of service separates the individual from useful results must be overcome, and under such conditions, to overcome is to achieve. But hard knocks as ends in themselves tend to dwarf and to enfeeble, and the process of taking them results in no achievement. Again, having arrived to a position of responsibility, the engineer too often discovers that the pressure upon him for results is greater than his ability and the time at his disposal can satisfy. He is not infrequently quite alone in the discharge of heavy obligations. Under these conditions he is prone to excuse himself from assuming many of the responsibilities affecting his citizenship. He is sometimes so occupied with the slide rule that he has no time to vote. He avoids religious and philanthropic duties and he becomes indifferent to the needs of his neighbor. Such defects, if they exist, narrow and weaken, and a tendency to yield to them constitutes a danger which the wise engineer will do well to guard against.

Just at this point the modern college of engineering assumes heavy responsibilities. Whether the methods followed by them in the past will prove altogether sufficient for the future is the question. We all know that in the administration of its work the college of engineering must enforce principles which demand the long continued and serious attention of the students. There are periods in this process when other things, however important in themselves, must give way to the main purpose at issue. The process, moreover, is, for the well-balanced man, a necessary and useful one. The student must be serious and devoted to his purpose, he must sometimes

fag until he is exhausted and then rest that he may fag again, but the fact must be clearly recognized that the full purpose is served when the principles to be learned have been assimilated. It is the possession of a new expression of truth that is to be prized; the grind is an incident. A criticism which may fairly be urged against the modern school of technology is that it so crowds its courses that one grind succeeds another so closely that the student is overwhelmed, and in too many cases the grind comes to be accepted for the truth. Obviously, the defect, so far as it may exist, is to be found in the system of instruction which permits the assignment of tasks which are not without an element of drudgery. The college needs fewer tasks and more of those aids which can only come from inspiring leadership. The student of engineering must have his chance to choose for himself, to exercise his individuality, to establish a good acquaintance with the library, to cultivate his tastes broadly, and in order that this may be done, the college authorities must be interested in conserving his time, in making it possible, without diminution in the amount of technique administered, for him to consider its relation to the broader aspects of life. The large purpose of the college is not that we may develop technicians, but that through technical training we may develop men who by their life and work will advance our ideals of American citizenship.

May I add here in the midst of this company of friends, many of whom are, I know, greatly interested in my problems, that it is my desire and purpose as a humble servant of the engineering profession of the State of Illinois to do what I can in our own College of Engineering to develop and to apply these conceptions.

Mr. Armstrong: I presume it is not necessary to formally introduce Judge Kavanagh to an audience in Chicago. Although we may not all know him personally, we all know who he is and what he has done for the city. I can say that we look forward with pleasure to the address by Judge Kavanagh on the subject of "Citizenship" from the viewpoint of the jurist.

Hon. Marcus Kavanagh: Friends and gentlemen: I feel rather abashed in this presence. I have always had a feeling of respect so profound that it almost amounts to uncanniness for the man who can add up a column of figures and have them come out twice the same way, and it gives me a sort of a shivery feeling to see in one room at one time so many men who are, in the language of the schools, "good at figures." An insuperable barrier to my ever becoming an engineer would be just the multiplication table. I have, however, for you, as I said, a very profound respect.

I am under handicap because Doctor Goss in his speech on Citizenship has said identically the things which I intended to say. He has said them much better than I would; still, I would have preferred the first chance at the subject. I am in the situation of one of my soldiers in the Seventh Regiment—and I am reminded of this story by the name—I trust, Doctor, that you will think that it is nothing except a coincidence that the soldier's name was Goss; he was an engineer named Billy Goss, and he had a brother in the same Regiment, and they both had false teeth. It is not a family trait, this wearing of false teeth, but in this case it was an accident. Now, one day we were fording a river and there had been recent rain, and the stream was swollen and poor Billy was fording the river, holding his blanket roll with one hand and his gun with the other, and the current running very swiftly, and while in this situation he dropped his teeth into the current and they were swept away, so after that when it came to dinner time Billy had to sit patiently by smoking his pipe until his brother was done with his dinner and then he borrowed his brother's teeth and ate his dinner.

And by the strangest coincidence, this evening I have to borrow the Doctor's teeth to get through with the subject that has been assigned to me.

I was instructed to take this blooming subject of Citizenship, and I follow it because I am instructed. Now, you have heard so many good stories tonight that I dislike to perpetrate this one, but I must, because it illustrates

my attitude here this evening, and this is also one of the stories about my Regiment. There was a fellow in the Regiment who was a great fraud,—a big Irishman six feet high,—and he was a fraud because no man could ever be as stupid as Manus looked. He had a head that was perfectly square, and you would think that nothing could ever be knocked into that head. I remember him being out on the guard line one day, and a little peppery army officer who was with us—one of the officers of the Regiment who before that had been in the regular army—was trying to coach him in guard duty, and to impress upon his mind the importance of the countersign, and how he was to perform his duty in regard to that. You know how sacred the countersign is; only a few men are to know it, and only those who are on duty are given the countersign. Well, Manus had this little fellow driven wild. As I came up to where they were I heard the officer say, "Now, see here, soldier, I am going to instruct you in your duty once more, and if you don't follow these instructions, you to the guard house. I am going up there on the hill, and when you see me coming you say: 'Who goes there,' and I will say, 'Friend with the countersign,' and then you say, 'Advance, friend, with the countersign.' Bring your gun to a charge and make me advance until my stomach touches the tip of your bayonet and then make me give you the countersign; make me whisper it, and if I don't give it to you don't allow me to pass; blow my head off first. Now, those are your instructions, do you understand?" "All right, sir," said Manus, and when the Captain came up to the hill Manus said: "Halt, who goes there?" The captain said, "Friend with the countersign," Manus said: "All right. Advance, friend, with the countersign, put your stomach against the point of my bayonet and says 'Gettysburg,' or I will blow the damned head off of you."

Now, I don't know Guito Saccharino whom Mr. Chamberlain quoted from; I have never heard the gentleman's name before, but I do know that there are places in this world where every man depends upon the strength of his own arm, and he is measured according to his own ability in the engineering line. Those places are in the new countries of the world, —in South America, in Africa, places which have not their own engineers, in untried and half-civilized lands,—and I do know that there, as against all the engineers of the world, the American engineer stands first. His genius and his brain, wherever he is, is equal to that of anyone; there isn't any engineer in the world who stands ahead of him. The old schools of the Old World may have greater advantages in technique. But in Mexico, in Africa, in the South American countries, the men who construct, the brains that dare in the constructions, that unfold the scheme and the nerve and courage that carries them out—there it is the brain and the heart of the American engineer! There is no finer illustration of it than right here in Chicago. We stop to consider, to measure this city of ours with great cities of the Old World. London, with its twelve hundred years of existence; Paris, with its eleven or twelve hundred years; New York, with its three hundred years; Chicago with its forty years—Chicago, not forty years old as they are old. Forty years ago it was not a crowd of pioneers with some money in their pockets going to start out to build the city from the new, it was a little band of men, broken in fortune, bankrupt, standing on the bleak shore of this Great Lake, looking at a pile of smoldering ashes, looking at the smoke which was carrying up to heaven their wasted fortunes and the garnered energy of their lives. They were standing beside the funeral pile of their fortune. It was worse than beginning from the new. And within forty years there has been built upon the shores of these magnificent waters this miracle city, this wonder city, this pride of the continent—Chicago.

Now, my friends, who did it. Was it the men with the capital that paid for it? Oh, they were necessary, but out of whose brain and whose heart came this scheme of brick and marble and steel which was one of the wonders of the world? Out of your profession, gentlemen. The men who

did it, who planned it, who are planning it today and building it and pushing it forward into greater activity, into greater wonder, are the body that is represented in this gathering here tonight. So I am proud, gentlemen, of the honor that you have done me to call me here, and I am glad that you have taken me out of my shop. Do you know, if a chemist is called upon to explain the cosmos, he will explain it by chemistry. When the geologist wants to explain the creation of the world, he will show you his stratifications; and everybody refers to his own particular line or his experience, and I suppose if an engineer was going to explain how the world was created or was going to be created, he would explain it according to the rules of his little science—of his great science—so a lawyer or a judge sees all things through the spectacles of his everyday experience. Pardon me if I talk for a few minutes tonight from my experience.

It is the fault of this intense life of ours—not the crime, but the fault, that comes from its very intensity,—that we as Americans are centered closely upon the particular things which we follow. We are reproached for it by people of other lands, and unworthy reasons given for it, but it is because we are a people of centered purpose, following the thing which is ahead of us with all the life and energy that is in us and laying other things a little to one side. Well, the day has come, as has been intimated this evening, for a change in that. Something tremendous in the way of sacrifice is required of American citizenship.

In one or two phases which appear before the courts there is a startling situation. Up to the north of us is a country separated from us simply by an imaginary line. Its people speak the same language which we speak, they have the same general laws which we have. In this country with us every year there falls by the hands of the assassin ninety persons out of every million inhabitants. In that country which is separated from us by this imaginary line there are homicides every year to the number of thirteen to every million inhabitants. With us mark there are ninety for every million; with them there are thirteen. Across the water is another country, speaking the same language, governed by the same traditions, from whom we borrow our laws, and the number of homicides to the million inhabitants is only nine; in Germany the number is only five to the million inhabitants. Remember, with us ninety, in Canada thirteen, in England nine, in Germany five. Even in despised Italy there are only fifteen to the million inhabitants. Now, my friends, what is the matter? What is the reason for this terrible situation? And it does not hold alone in regard to homicides, but to all the serious crimes, robbery, burglary, arson, theft. You know, my friends, that in the County Jail in Cook County on the North Side last Christmas sixty murderers sat down at the same table to dinner. Sixty men accused of murder sat down to dinner in the County Jail on the North Side in the city of Chicago. They had a good dinner and later the singers from the Opera went over and sang to them. I am afraid their victims—the little children that they had made orphans and the women whom they had made widows—were not sitting down to as fine a dinner and nobody was paying any attention to them.

Last fall a poor fellow with a wife and a little baby fourteen months old got up at three o'clock in the morning—that is earlier than I ever got up excepting to go to bed—but he got up at three o'clock in the morning and in driving his little market wagon into town, five men attacked him. He got down on his knees and said, "Take what I have, but let me go home to my wife and my little baby! Don't kill me!" But they killed him, they beat his head in; then they half buried him; they had no more regard for his dead body than if it were the dead body of a chicken. They left him there and not one of the murderers felt one whisper, one pang of regret or remorse until they were caught. They were caught and there was no defense, no question about their guilt. They were convicted and they were sentenced to be executed. And then the thing happens which shows where the fault lies largely: The day approached when the law was to be vindi-

cated, and terror was to be put into the hearts of others as merciless and cruel as they; a crowd of good hearted and good intentioned people got together and petitioned the Governor to save them from their just fate, and the people are now taking up a subscription to pay the expenses of an appeal to the Supreme Court. It is a remarkable thing in the face of that subscription and that activity in their behalf that there has not been one piece of money given or anything thought of being raised for the distressed widow and for the desolate little baby over there that are left behind. But neither to you nor to me has it ever occurred to give one dollar to the victims of that murder, and yet there will be a thousand dollars or two thousand dollars raised for the murderers.

Now, my friends, what does this show. Simply this: We have not enough of the fear of the law, and we have not enough respect for the law. Who is to blame for it? Well, it is time for plain speaking. The people who are to blame first are the people in whose hands is most nearly entrusted the administration of the laws, the judges of the courts and the lawyers who practice at the bar. Next, and ultimately, the persons who are to blame are the men who hire us—our masters—you. The persons who hire the judges and who hire the lawyers, the men who control the public sentiments—you—the citizens of Chicago. Now, what is the remedy? What is the first step?

The first step in some way is for associations like this, this association, lay associations. The lawyers will never accomplish anything; why, in their hands for years have been these questions, and the only thing a bar association ever does is to tinker with them, never go to the heart of these things. Every great reform in procedure in this country and in England has been made, not because of the bar, but in spite of the bar. Very frequently, as I am sitting up there as a judge, I have questions being argued before me. One side says one thing, the other side says another. Presently one of the lawyers brings down an old volume—a case that was decided a hundred years ago—and reads me the opinion and that settles it with me. It is the end of argument on either side. It is the decision rendered a hundred years ago and that decides. By that sort of training we necessarily get into the habit of mind that we think and believe that whatever is in the law is right, whatever is established is right, and innovations are wrong. And the last thing which a lawyer will do is a revolutionary change in the methods of procedure, but pressure will have to come from the outside, it will have to come from institutions like this.

What is the next thing? Whenever you are chosen to sit on a jury your citizenship calls out to you to go, and when you go and you go to the criminal court, enforce the law whoever it helps or whoever it hurts.

A street-car conductor, a villainous fellow, was in the habit of abusing his wife, and she starts to get a divorce from him, and a decree of injunction is served on him in the afternoon to keep away from her because she is afraid of him. An hour after the decree is served on him he purchases a revolver, walks up to the house where she is, puts the revolver against her stomach, and fires twice. She is about to become a mother; he kills her and the little baby in her breast, and turns to the mother of his wife, chases her out where she takes refuge under the porch, and there kills her. He is taken, placed in jail and afterwards is tried before a jury, and there isn't any defense to that. The defense he puts up is absurd; the jury must find him guilty, but they give him a punishment of thirty years, nominally, which means with the usual good time allowance fourteen years in the penitentiary, as punishment for extinguishing three lives.

A young Italian was living with an older man who had a young and good looking wife. He takes this wife, steals her from his host, and takes her out to Iowa with him. The girl is conscience stricken and returns to her husband. This young Italian follows her to the house, kills her husband in her presence, and takes her again. He is tried, there is no defense practically, and he is found guilty of manslaughter, which means about five

years in the penitentiary. Now, the juries do that. In this case what their verdict amounted to was simply to pardon the fellow. They found him guilty, they said, "yes, he is guilty, but we pardon him."

Now, my friends, we need a year or two of good iron administration of the law; that when a man is proven guilty before jurors they will find him guilty; that when he is guilty and found guilty he will be punished. I do not believe in merciless punishment; I believe the young man who makes a mistake for the first time under sudden temptation ought, if possible, not to be punished; let him see the danger in which he places himself by wrong doing; let him be warned so he won't do it again. But the vicious fellow, the man of vicious life, whether he has ever been convicted before or not, the man who does a thing with malice in his heart, the robber, the burglar, the murderer, should get such punishment as will not only be a lesson to him, but will be an example to others similarly inclined. And unless you, gentlemen, and the public will turn in and serve on juries and do that thing, unless the courts will take their nerve and enforce the law, this thing will continue. Now, it is up to us, my friends,—and I am taking advantage of your hospitality in a mean way to say disagreeable things to you, to harp on disagreeable things, on what may not be an agreeable subject, but still it is my only justification for coming.

I want to thank you for the attention which you have given me and to hope that when calls are made upon you as they may be made, and upon your association as they may be later, you will respond for improvement in the law, for the enforcement of the law, for the betterment of the community, for the good of the state, for the honor and glory of God.

BOOK REVIEWS.

Electro-Analysis. By Edgar F. Smith, Blanchard Professor of Chemistry, University of Pennsylvania. P. Blakiston's Son & Co., Philadelphia. 5th ed., revised and enlarged, with 46 illustrations, 1911. Flexible leather; 7¼x5 in.; pp. 332, including index. Price, $2.50 net.

The work of Professor Smith is so well known that a new edition of his work on Electro-Chemistry will always be welcomed by chemists interested in analytical chemistry. The present edition contains as new material essentials of all that has appeared on electro-chemistry during the past four years; it includes a description of the devices, working tables, etc., in an electro-chemical laboratory. This is followed by an excellent historical sketch of the subject, theoretical consideration and methods for the rapid precipitation of metals in the electrolytic way, and the use of a mercury cathode. Chapters on the determination and separation of metals follow. The determinations of the halogens and nitric acid are described, as is also special application of the rotating anode and mercury cathode in analysis. Chapters on oxidation by means of the electric current and combustion of organic compounds complete the book. Numerous examples of the accuracy of the determinations and actual laboratory results are given. The methods and experiments are described with sufficient detail, and the book contains an excellent index. It is well printed on good paper and is serviceably bound. W. H.

The Contractor's and Builder's Pocket Book. By Wm. Arthur, author of "The New Building Estimator." David Williams Company, New York, N. Y. Flexible cloth; 4½x7½ in.; pp. 384; numerous tables. Price, $2.00, postpaid.

This book is not written for engineers, but for builders and building contractors. Engineers, however, do spend money occasionally for books, the reading of which help pass away the time, and therefore this book should be read by all engineers. The author deals with the contractor as a business man and handles architects in no gentle manner. That is, architects of a certain kind who are full of book learning and lack practical experience.

In the second part of his book he deals with the contractor as a constructor, which he says, "is not a trained architect by any means," a conclusion the average engineer will reach after reading the section. The third part of the book deals with the contractor as a citizen and taxpayer.

The author has an amusing and entertaining style which makes the book decidedly readable. It is filled to overflowing with good sense in nuggets. No better book could possibly be put in the hands of young engineers and architects, to give them a proper idea of their relations with contractors. All the hard-headed common-sence ideas picked up by a man of large experience in building work in several countries are here given for the benefit of the readers. Older engineers often look back to many pleasant hours spent in the company of shrewd old veterans in the contracting game and feel thankful that they had the privilege. Until young men do get similar opportunities they can do no better than read this book by Mr. Arthur and read also his book on building estimating, which, however, he rather brazenly, with apparent total lack of modesty, advises himself several times. E. McC.

Engineering as a Vocation. By Ernest McCullough, Consulting Civil Engineer. David Williams Company, New York. Cloth, 8x5½ in.; pp. 201. Price, $1.00.

In this the latest book from Mr. McCullough's pen, he has ventured into a new field and has said some of the things most experienced engineers have felt, but have not put into words, in reference to the engineering profession. For many years past the advertising men of various commercially-organized schools have managed to keep the public mind imbued with the idea that an engineering education is the "Open Sesame" to unlimited opportunity, and with the result that the engineering profession is as badly crowded with incompetents as are the other learned professions of law and medicine.

The reviewer ventures the opinion that many men who have spent years in engineering work will find herein for the first time a statement of the fees obtainable by a consulting engineer for ordinary classes of work. If the engineer be fortified by a big reputation, the fee is liable to be measured—as in the case of a famous lawyer or doctor—more by the reputation of the one retained than by the value of the work to be done, and the glamour of these occasional big fees and salaries played upon by the newspaper paragrapher results to the detriment of the profession generally.

Himself a consulting engineer of wide experience, the author shows his faith in his chosen field in a way few men do, viz., by the fact that he is educating his eldest son as an engineer that he may succeed to his father's practice. He by no means seconds the view of the late R. T. Crane, that well-known antagonist of all higher education, by deprecating the work of the technical schools, but makes a plea for greater care in selection of raw material from which to mould the future engineers of the country, in the hope that thereby some of the incompetents may be eliminated. As such the book is deserving of a place in the library of any man about to choose a vocation for his son. G. F. D.

MEMBERSHIP.

Additions.

Allen, Edwin W., Chicago..........Member
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Armsby, Charles L., Chicago..........Associate Member
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LIBRARY NOTES.

The Library Committee desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

Milwaukee Bureau of Economy and Efficiency:
Bulletin No. 6, Citizens' Free Employment Bureau. Pam.

Francis E. Nipher, St. Louis:
The Elimination of Velocity Effects in Measuring Pressure in a Fluid Stream. Pam.
Pressure Measurements in a Fluid Stream. Pam.

Charles J. Poetsch, M. W. S. E.:
Annual Report of City Engineer, Milwaukee, 1910. Cloth.

Ernest McCullough, M. W. S. E.:
Engineering as a Vocation. Cloth.

George M. Wisner, M. W. S. E.:
Report on Sewage Disposal, Sanitary District. Pam.

Harbison-Walker Refractories Co.:
A Study of the Blast Furnace. Cloth.

Slason Thompson:
The Railway Library, 1910. Cloth.

Jesse Lowe, M. W. S. E.:
First Annual Report of Transactions of Association of Drainage and Levee Districts of Illinois. Pam.

C. W. Standiford:
Report on Proposed Plan of Operation for Jamaica Bay Improvement.

J. H. Warder, M. W. S. E.:
Report of the Sub-Committee on Harbor Development to the Committee on Harbors, Wharves and Bridges.

J. B. Davidson, Ames, Iowa:
Transactions American Society of Agricultural Engineers, 1909. Pam.

H. A. Allen:
Proposed Specifications, Forms of Bond and Contract for Pumping Machinery, Lake View Pumping Station, Chicago.

McGraw-Hill Book Co.:
Geodetic Surveying, Edward L. Ingram. Cloth.
Strength of Materials, James E. Boyd. Cloth.

EXCHANGES.

West Virginia Geological Survey:
County Reports, 1911, West, Roanne, Calhoun Counties. Cloth and Maps.

Association of Ontario Land Surveyors:
Annual Report, 1911. Pam.

Canada Department of Mines. Mines Branch:
Summary Report of the Mines Branch, 1910. Pam.
Report on the Molybdenum Ores of Canada. Pam.
Report on the Gypsum Deposits of the Maritime Provinces. Pam.

Canadian Society of Civil Engineers:
Transactions, January-June, 1911. Pam.
Index to Transactions, Vols. 1-25. Pam.

Institution of Civil Engineers, London:
Proceedings, September and November, 1911, Pam.

Institution of Mechanical Engineers, London:
Proceedings, March-July, 1911. Pam.

National Association of Cotton Manufacturers:
Transactions, Annual Meeting, 1911. Bds.

New York Public Service Commission, First District:
Annual Report, 1910, Vol. 1. Cloth.

Brooklyn Engineers' Club:
Proceedings, 1910. Cloth.

Philadelphia Bureau of Surveys:
Annual Report, 1910. Cloth.

Oklahoma Geological Survey:
Bulletin No. 8. Cloth.

New York Public Service Commission, Second District:
Annual Report, 1910. 2 vols., cloth.

Ohio State Highway Department:
Bulletin No. 14. Pam.

Institution of Engineers and Shipbuilders in Scotland:
Transactions, 1910-1911. Cloth.

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NOTES ON STRUCTURAL STEEL DESIGNS.

ALBERT REICHMANN, M. W. S. E.

Presented November 8, 1911.

Structural steel nowadays is used so very extensively in the construction of our railroads, industrial buildings, office buildings, apartment buildings, and in almost every means of conveyance, that it represents a large part of the capital outlay in our railroad, industrial and real estate undertakings. For this reason it is of the utmost importance that the most rigid economy be exercised in its use. By an economic design is meant a design wherein the cost of material and labor entering into the construction of said design, will be a minimum. In other words, the writer considers a well designed structure one which will most efficiently perform its function with a minimum outlay of capital and the lowest annual maintenance charge.

One of the most important features of a material to be used in construction work, consists in the ease and simplicity, together with the safety and reliability, with which one member can be attached to another. In the case of wooden construction it is almost impossible to make a connection of one member to another with any degree of certainty and use ordinary factors of safety. In the case of reinforced concrete, or, more properly speaking, concrete reinforced with steel, where the joints are largely dependent upon the adhesion of the concrete to the steel, the question of connections is an uncertain problem. In structural steel, owing to its homogeneous nature and uniformity of strength, it is possible to mathematically determine the value of connections of one member to another with reasonable margins of safety and secure a perfectly safe structure. Owing to the importance of securing reliable connections of one member to another, it is perfectly natural that the type of connections used in steel structures should be one of the most important subjects to be considered in structural steel designs. It will be observed that the question of connections is, therefore, given very careful consideration in this paper.

The first iron and steel bridges designed by our American engineers were typically American. That is to say, our type of construction was radically different from that used by other nations. The question of cost was given the most careful study, and justly so, as the railroad companies which purchased these structures had a very difficult time to make both ends meet. In those days the rolling stock of our railroads was very light; the volume of traffic was very small, and the trains did not move over the railroads with the high speed of today.

The type of structure referred to is the pin-connected span. When first introduced it was built of any length, ranging from 30 ft. upwards. It was very popular owing to the small amount of metal required in its construction, the ease with which its members could be transported over great distances, and the facility with which it could be erected. These bridges were built at a time when the science of building structures of metal was in its infancy. As a consequence most of the old-time bridges were built with very inferior details. Owing to the rapid increase in the weight of the rolling stock of the railroads, they were soon taxed to their capacity and unfortunately sometimes beyond their capacity. As a result it did not take long for these old-time bridges to develop imperfections and it soon became apparent that the pin-connected bridge was not the ideal type of structure to be used in every case.

The next step was the introduction of the plate-girder bridge and the riveted-truss bridge, and it soon became common practice to build plate girders for all spans from 20 to 75 ft. in length, and from 75 to 125 ft. various forms of riveted trusses, and spans over 150 ft. of the pin-connected type. In other words we began to follow the practice of European engineers in the building of our shorter span bridges.

Now let us analyze why we departed from the old-time practice of building pin-connected bridges and substituted the use of the riveted bridges. In the first place the old time pin-connected span was used without consideration of span length. The shorter pin-connected spans, owing to their extreme lightness, the small moment of inertia of their tension members, poor lateral bracing, and generally inferior details, vibrated excessively under traffic. The fact that these small pin-spans were used out of the sphere which naturally belonged to them, led a great many engineers to abandon the pin-connected span almost entirely and of recent years we have adopted more extensively the use of the all riveted span for our longer span bridges. It has occurred to the writer, however, that in many cases we have substituted riveted spans for our long span bridges where a pin-connected structure would have been preferable.

The ideal span to build would be one that is free from vibrations and without secondary stresses, but as this is impossible, the problem then is to select that type of design which has the minimum number of objectionable features. For an ordinary simple truss span there are four types of construction to be considered:

First, the truss with built up chords and diagonals and riveted connections throughout, or what is ordinarily called a riveted span. In this type of construction the span should be made as deep as good designing will permit. The dimension of the chords and web members should be made as narrow in the plane of the truss as permissible. By increasing the depth of the trusses the connections of the diagonals to the chords become smaller; the deformation of the truss under load becomes smaller and consequently the secondary stresses become smaller.

The problem of selecting the proper dimensions of the various members forming a joint requires a great deal of skill and judgment. In the first place the various members should be slender, so as to be as flexible as possible, in order to reduce the secondary stresses due to the bending of the member. On the other hand, with slender members it is exceedingly difficult to concentrate the rivets in the connections. This calls for the rivets to reach far out into the members; hence the use of large gusset plates. The longer the connection becomes, the more uncertain the action of the rivets, and therefore the more objectionable the connection. The size of the gusset plates may, in many cases, be reduced by connecting the main member to both sides of the gusset plate by means of an auxiliary connecting plate. By this means the rivets connecting the main member to the gusset plate take double shear and thus the number of rivets can be reduced in proportion.

The slenderness of members calls for compression members with small moments of inertia, and therefore they are not so economical as a column as one with a greater moment of inertia. In the case of tension members it means thicker material and, therefore, more waste due to deductions on account of rivet holes.

Thus we are confronted with the problem of selecting members having large dimensions of their cross-section in the plane of the truss, with the possibility of their connections being concentrated to a minimum, and, as a consequence thereof, of having large secondary stresses due to bending of the connecting members. Or, on the other hand, selecting a cross-section with the least width possible, which in turn calls for small moments of inertia; that is to say, the members are not economical compression members, nor are they economical tension members, as the material becomes too concentrated. The great problem is, therefore, to know just where to draw the line in the selection of the various members.

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In order to somewhat overcome the effects of the secondary stresses in riveted-truss spans, some of our specifications call for their partial elimination by lengthening and shortening the various truss members, amounting to the respective distortions due to dead load plus one-half the live load, and reaming of the chord splices, while the chords are assembled in a straight line, and then forcing them in their proper position before the connections of the diagonals to the chords are drilled or reamed. This is all right as far as it goes in the shop, but when the structure is actually being erected it is an altogether different proposition. If the chords were first riveted together and then put on their camber blocking before they were connected to the diagonals, these results might in a measure be obtained.

Before a long fixed span can be swung it is necessary to rivet all the tension splices in the chords, so that it is very probable that a large part of the refinement that was put on this work in the shop is lost in the field.

Second, the truss with built-up continuous chords and built-up diagonals, pin-connected throughout. The vertical posts and diagonals are connected to the chord by means of pins, which in the case of a continuous chord become very small, owing to the fact that the pins merely transmit the increment of the stress to the chords. It is sometimes found desirable to rivet such posts and diagonals, as in case of reversal of stresses in these members, in order to avoid the wear in the pin holes. In such cases the stresses to be transmitted to the chords are very small indeed; consequently the connections are small and, therefore, secondary stresses are also very small. This type of construction can be designed by making the chords sufficiently shallow in order to make the same flexible and the diagonals sufficiently wide in the plane of the truss, so that they are sufficiently strong to rotate upon the pin and overcome the pin friction when the structure deflects. It is believed that this type of construction has a minimum amount of secondary stresses.

The only objection to this type of span is that it weighs more than a span with eye-bars used as tension members, and that the tension chords must be spliced in the field before the span can be safely swung, which in many cases is very objectionable as in most long-span bridges it is desirable to make the span safe in the least time possible.

Third, the truss with the chords built up and made shallow in order to be flexible; diagonal eye-bars, pin-connected.

Fourth, the truss with bottom chords and diagonals made of eye-bars. While this type of construction is pin-connected throughout and theoretically articulated, the joints are actually more or less rigid, due to the friction of the bearing of the eye-bars on the pins. In order to reduce to a minimum, the second-

ary stresses due to pin friction, it is desirable to make the bars as wide as permissible and still not exceed the allowable bearing value of the eye-bars upon the pins.

It is extremely difficult to determine the amount of secondary stresses in a pin-connected bridge, due to the weight of the bridge itself, inasmuch as it is impossible to determine the frictional resistance upon the pins which the various members encounter in righting themselves, while the camber blocking is being removed and the span swung.

While the action of eye-bars in a structure is not perfect—that is to say, that bars have more or less secondary stresses—nevertheless, they are one of the safest articles used in the construction of a bridge. When we are using an eye-bar we can feel that we are using something about which our knowledge is reasonably complete. It seems to the writer, however, that it is the common practice of engineers either not to use eye-bars at all or else to use them right up to the limit of their capacity as determined by full size tests. They seldom figure out what amount of economy could be obtained by using an eye-bar with a somewhat lower unit stress on the same basis that they use a riveted member. In the case of a bulit-up tension member, there is a large amount of material which is wasted, inasmuch as it does not enter into or carry part of the primary stress; namely, such material as is added to take care of the deductions from the section, necessary on account of rivet holes, and material added for lattice-bars, batten plates, etc. If they realized that they could add considerable material to their eye-bars and still use them with economy, they might not be so adverse to their use. This material added to the eye-bars would reduce the normal stress in the eye-bars to such an extent that the secondary stresses could be entirely ignored.

The vibration of pin-connected spans may be reduced in several ways. *First,* by making all of the members built-up, with, comparatively speaking, large moments of inertia in the plane of the truss; *second,* by making the eye-bars sufficiently wide so that their deflection, due to their own weight, will not be too great; *third,* by weighing down the bridge by means of a ballasted floor. The writer cannot help but feel that when we come to our longer span bridges, the pin-connected type bridge is the proper one to build. The main advantages of a pin-connected span with eye-bar tension members, are that it weighs less than other types of construction and can be built in the shop with extreme accuracy so that there is little possibility of encountering trouble in erection through faulty workmanship. Erection can proceed with greater rapidity than with the riveted span, and the writer believes that less skill is required in designing a pin-connected span than a riveted span.

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Lateral Bracing.

There is a feature in our long span bridges which should be considered very thoroughly, and that is the question of lateral bracing for the compression chords. In the shorter span bridges the loads allowed for wind bracing are ample to provide sufficient material to take care of the actual wind stresses, and also to hold in alignment the compression chords. However, in very long span bridges, the question of providing sufficient lateral bracing for the compression chords to hold them in proper alignment, so that the compression chords will act in unison throughout their entire length and in reality form one compression member when considered in a horizontal plane, should be carefully considered. In this respect the lateral bracing, in addition to performing the function of wind bracing, also performs the same function that the lattice bars do to the individual compression members. However, in the case of an ordinary member the lattice bars connect continuous members, whereas, the lateral bracing must hold in alignment members which are not thoroughly spliced, and are, therefore, more liable to be out of true alignment on account of imperfect workmanship.

It is not an easy matter to determine the amount of lateral bracing which it is necessary to provide to hold the compression chords in proper alignment, owing to the fact that we have not made sufficient tests of large size compression members to determine just how much material is required to hold in proper alignment the main sections of a compression member.

This same question of uncertainty applies to the proper bracing of the top flange of our through plate girder bridges. The writer is well satisfied that a large number of our designers do not have the same margin of safety in the compression flange of their through plate girder bridges as they have in the tension flange. Some recent tests of plate girders show that the ultimate strength of the top flange is about the elastic limit of the material. In order to make the top flange of a through plate girder bridge the same strength as the bottom flange, we should have some formula to guide us in the proper proportioning of the top flange. A formula for this purpose can be developed only by a series of experiments. However, in the meantime it seems to the writer that we should apply our column formula to these flanges. Of course, the value of intermediate supports should be given proper consideration.

Another feature in our plate girder designs, which the writer is inclined to believe will cause our engineers some regret, is that they have not as a rule increased the thickness of their web plates in the same ratio that they have increased their flange areas. This is especially true of the long plate girder spans. When the large web plates are rolled at the mills the

edges of the plate cool first which causes the plate to become "dished." In order to eliminate this dishing or buckles in the web, it is necessary to put these web plates in the bending rolls until the buckles are eliminated. After this the plates are straightened for use. There can be no question but what there are heavy secondary stresses in all these large web plates. In addition to this the web plates are more exposed to corrosion than any other part of the structure and if there is any deterioration in this structure, the web plates will show the greatest portion of this deterioration.

In many cases stringers and the shorter span plate girders could be built not only better, but also cheaper, by omitting stiffeners altogether, except at end connections or bearing points and in cases where necessary on account of other connections, and putting a like amount of material in the web, thereby obtaining a much stronger web and adding some to the strength of the flanges.

It frequently happens that heavy portal or sway bracing is attached to the upper part of bents, leaving the lower portion unbraced, and due consideration is not given to the bending which this portal or sway bracing might induce into the columns; the columns are merely provided with ordinary lattice bars below the portal or sway bracing instead of being provided with proper web plates or cover plates to transmit the shear to its proper destination.

Lattice-bars should be eliminated where it is practicable, inasmuch as their function consists merely in holding members together, and they do not assist materially in transmitting the main stresses, whereas, if a solid plate were used it would form a part of the member as well as take care of any local shear that might be manifest.

In order to get accurate workmanship in large compression members, they should be so designed that they can be completely assembled in the shop before riveting. This practically means that even some of the smaller compression members should have lacing bars with at least two rivets at each end, in order to keep in proper alignment the members while they are being riveted in the shop. The larger members should have sufficient diaphragms to insure the proper amount of rigidity.

There is a tendency among engineers to over-rivet their compression and tension members to make the material act as a unit, and it often happens that the material is weakened by this means. Material should be used as it comes from the mills with as little labor on it as possible.

In many cases the specifications call for symmetrical sections, but do not mention the fact that the connections should be symmetrical or at least an equal number of rivets on each side of the center line of the member.

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Some engineers are inclined to lay down rules to others which they themselves are not following—for instance, in trough floor construction used extensively for track elevation purposes. These troughs are filled with concrete and become inaccessible for painting and inspection. The writer believes that much better results might be obtained by using I-beams and reinforced concrete decking on top of the I-beams with ballasted floor on top of the concrete. In this way the structural material is always accessible for painting and inspection.

In the designing of our mill buildings, especially where high speed traveling cranes are used, special attention should be paid to the proper distribution of the lateral forces induced by the traveling cranes throughout the building. In cases of this kind, the bottom chords of the roof trusses should be provided with a good lateral system extending the full length of the building, so that the lateral forces will be thoroughly absorbed throughout the structure.

Nickel Steel.

Of recent years some of our engineers have been advocating the use of nickel steel and other steels of high ultimate strength. Inasmuch as the modulus of elasticity of nickel steel is the same as that of carbon steel, the structures designed with these steels of high ultimate strength, where the unit stresses are from two and one-half to three times those used for ordinary carbon steel, the deformation and deflections will be from two and one-half to three times those of structures built of ordinary carbon steel. As the deformation of the structure increases, the secondary stress also increases in proportion. What is more, even if the secondary strains have been rectified for the dead load, the deflections due to the live load will be much greater in proportion in structures of nickel steel than in those of carbon steel, for the reason that the weight of the live load in this case is much greater in proportion to the weight of the dead load than is the case where ordinary steel is used. In addition, the deflections caused by the passing of the live load over the structure are much greater owing to the increased unit stress employed.

For the above mentioned reasons, structures built of steel of high ultimate strength should be designed with the minimum secondary stresses. One of the worst features in connection with the use of nickel steel has been that some of our engineers have used carbon steel in conjunction with nickel steel. Take the case of a simple truss span, where the chords are made of nickel steel and the lateral bracing is made of carbon steel. The two chords are tied together by the lateral bracing forming one compression member, and any deformation which takes place in the chords due to the compression of the same must be borne proportionately by the laterals. This means that the lateral

bracing may be stressed up to its elastic limit, while the chords themselves are not stressed beyond their usual requirements.

In stating that nickel steel and carbon steel should not be used together, is meant in such parts of the span that act in unison. For instance, there can be no objection to the use of carbon steel in a nickel steel structure for floor beams and stringers, or such members as act independent of the main structure, provided ample provision is made for the stringer connections to expand. These are points, however, which can be taken care of in the design of the structure.

Secondary Stresses.

The future development of our bridges depends upon the careful consideration and elimination, as far as possible, of the secondary stresses. It will be observed that in none of the various types of spans considered is it possible to eliminate entirely the secondary stresses in the chords. The secondary stresses may be reduced by the selection of the proper section for the diagonals and their attachments to the chords. Secondary stresses are developed in trusses through the connections of the lateral bracing and the floor system. In a through bridge the elongation of bottom chord produces an elongation in the bottom laterals, resulting in heavy secondary stresses in both the floor beams and laterals when they are attached to the stringers and intermediate points. In a deck bridge the top chord being in compression is reduced in length, while the bottom flange of the stringers is elongated more or less, for which reason the stringers should be provided with extension joints at the floor beams in order to avoid excessive secondary stresses.

To minimize the effect of secondary stresses in a truss, it is well to omit knee bracing and sway frames at intermediate panel points.

The main posts of a truss should be made the full depth of the truss wherever possible; in other words, bracing to increase the efficiency of posts and the use of sub-struts, materially increases the secondary stresses. Floor beams should be made deep and centrally connected to the posts. In order to avoid chord stresses to be transmitted to stringers, their end connections should be made flexible. This can be done by using a wide gauge of the outstanding leg of the angle connecting the stringer to the floor beam.

When a truss with subdivided panels is used the unit stress of the floor beam hangers should be very low so as to keep down the elongation in same, as the elongation of the hanger produces heavy secondary stresses in the chords to which it connects.

Aside from the make-up of the various members of a truss

span and their connections, a great deal depends upon the type of span itself. Secondary stresses are very materially increased or decreased according to the type of the truss, whether it is a single intersection, a multiple intersection or a multiple intersection with vertical posts or without vertical posts.

Another source of secondary stresses in a truss is due to the fact that the bottom laterals are, as a rule, attached to the bottom of the post quite a distance below the bottom chord, so that the chord stresses in the lateral system must travel through bending in the post into the bottom chord. Besides this defect, laterals are not generally run in centrally with the chord, thereby inducing uneven distribution of chord stresses.

Discussion.

John Brunner, M. W. S. E. (Chairman): We are greatly indebted to Mr. Reichmann for preparing this paper and presenting it to us tonight. He has pointed out some of the principal features that should be thoroughly investigated in designing steel structures, and while the paper relates to designs of bridges, most of the principles apply to other structures as well. It is a paper that is of unusual interest to the structural engineer, and I hope it will bring out a good discussion.

J. M. Johnson: Referring to Mr. Reichmann's investigation of secondary stresses in ordinary trusses, I would ask about what percentage is usually found to exist. I have had occasion to look into that matter myself and would like to have a verification.

Mr. Reichmann: The amount of secondary stresses in per cent of primary stresses varies considerably for different structures. Engesser mentions a riveted Pratt truss of 150 ft. span, 28 ft. deep, in which this percentage in the chords runs up to 32, in diagonals to 19, and in the posts to 33. If this same truss were pin-connected in the usual way, having continuous top chord, it would be on an average 10%. In another riveted Pratt truss of 130 ft. span and 26 ft. depth, mentioned by Gehler, the percentages run from 6 to 22.

Mr. Johnson: Not in ordinary trusses. If you have a through riveted truss, say 150 ft. span, with a depth of 30 ft., you would not have anything like 20% to 25% secondary stresses.

Mr. Reichmann: We would have nothing less than 20%.

Mr. Johnson: My investigation was about 10%, Mr. Reichmann. It was for a truss 373 ft. long and 70 ft. in depth. I found from 10 to 11% secondary stress.

Mr. Reichmann: The percentage varies a great deal with different members, depending upon the section of a member.

A. F. Robinson, M. W. S. E.: While I agree fully with the speaker of the evening, there are one or two items which we

have discussed together several times, as the matter of thin webs in girders, floor beams, stringers and so on. He has always taken one side and I the other. Take cover plates on chords and girders, flange angles, chord angles, etc.—they are almost invariably run through a set of cold rolls to straighten them out. If they are not run through rolls, the cover plates are put into the gag and wherever they are gagged the metal is unquestionably stretched beyond the elastic limit. If the matter of straightening out web plates when they buckle is of so much importance, it seems to me the same applies with a good deal more force to the flanges of the girders and to the chords of bridges. The web plates in girders only take shear, and this can be largely overcome by the use of proper stiffeners.

I do not mean stiffeners placed in a helter skelter manner as though they had been fired in with a gun. I mean stiffeners proportioned consistently. Take web plates of the girders, wide sheared plates, if you will. The plate near the edges is pinched down to the thickness called for, and it thickens up toward the middle of the plate. The rivets are put in according to the theoretical bearing or shear in the edges of the plate. We have the extra thickness toward the middle of the sheet, where it is required. As long as we have our shear and bearing within due limits, it seems to me we need not worry about putting a lot of extra metal into the plate. If we can make our web plates of sufficient thickness so that we do not need stiffeners, well and good, but there are few designers who (even when they put in heavy web plates), do not shove in stiffeners and get just as many as where they use the lighter webs. In my own practice I have been watching for sixteen years a series of bridges of 105½ ft. span, where the web plates of the girders were ⅜ in. theoretically. The girders are 114 in. deep. They were designed for our old standard loading, 139 ton engine, and for twelve years we have been running heavy loads over these bridges, that is perhaps 70 % excess in weight over the loads for which the bridges were designed. We have yet to find the slightest indication of weakness or any serious wear. I think we should consider both sides of that question. We can make the web plates too thin, and, on the other hand, we can make them too thick.

Andrews Allen, M. W. S. E.: We are under great obligations to Mr. Reichmann for bringing this matter up once more, as we have not had a paper on bridge design for some time. It is a live question, and I do not believe that the details of ordinary bridge work are given nearly enough attention, so far as the question of economy is concerned. Many people seem to look at a girder as "only a girder," and too simple to pay much attention to, but my experience covering a good many years of designing and examining other people's designs, shows that even in the

simplest forms of bridges there are enormous differences in efficiency and economy; in the right use of metal; proper consideration of shop work, and things of that kind. These things ought to be given attention in the least important as well as in the most important structures, for this lack of economy runs up into enormous figures in the long run. Take the bulk of the bridge work done for the railroads of the country during any year and the total weight of metal, I venture to say, exceeds by many times the weight of the monumental structures that we hear so much about; yet the details are given small attention.

One of the reasons for this, I believe, is the tendency for standardizing. Standardizing is a good thing from an executive standpoint. I mean to say that when we have a standard we can use it readily and without investigation, and that very ease in its use leads to its abuse, because it is used where it ought not to be. A standard is all right, so long as our standard keeps moving—as long as we revise our standard often enough to keep abreast with the best practice and the conditions that change from time to time; for the art of bridge designing has been revolutionized in the last ten years, and I presume it will be revolutionized again—perhaps time and time again—until we get something that is really good.

In regard to the thickness of web plates, I am inclined to agree with Mr. Robinson, that there is a golden mean to be observed. Wherever we can avoid stiffeners without loss of economy by putting more metal in the web, I believe in doing it and I do it every time I can, but as far as wear on the web is concerned, I have examined a good many old bridges and have never seen one where the web had deteriorated as much as the flanges. It is vertical and does not catch refuse or water as the chords do, is quite well sheltered, as a rule, and can be easily painted; while the other parts of the bridge are harder of access and catch refuse, brine drippings and other things which cause deterioration.

In regard to the point Mr. Robinson brought up as to the thickness of web plates on the edge, that depends a good deal upon whether the web plates are ordered by weight per square foot or by gauge. The usual practice in lump sum contracts is to order by weight per square foot and then one does not get the thickness. I think in every case where rivet bearing is essential or where the web plate is of minimum thickness, it should be ordered by gauge and not by weight.

In regard to secondary stresses, a great deal has been written and a great deal has been said about them, and a great deal, I think, remains to be said. The fact of the matter is that no one knows just what the secondary stresses are. We can figure them on a theoretical basis and still we know that the result is not correct, because we know that the effect of the

stiffness of the joints and of the floor is to reduce the deflection of the span. The bridge members come into equilibrium somewhere. We do not know how much the secondary stresses are, but they are always less than our theory would indicate. Then, a bridge that has high secondary stress is usually very stiff, for the reason that the joints are stiff; and if we attempt to relieve ourselves of secondary stresses we often do so at the expense of stiffness of the bridge. So it is a matter that has to be handled with judgment; and I think it is entirely allowable to permit higher values for secondary than for regular stresses, for they occur only at certain points, they are not continuous, and usually have a tendency to relieve themselves.

Mr. Robinson: I want to say that I have never been guilty of ordering web plates by weight. I always ordered by gauge.

W. C. Armstrong, M. W. S. E.: Referring to the question of treatment of top flanges on through girders, the author of the paper spoke about introducing some form of compression formula, regarding the top flange as a column, but I have never been able to see just how that could be applied, for the reason that we have to take into account the support given by the gusset plates to the top flange. It is a question that certainly should be given consideration, and we seldom do properly consider it. I would like to have Mr. Reichmann tell us if he has any particular rule or formula for applying to the top chord of through girders.

Mr. Reichmann: I applied the formula on several occasions where we built very long plate-girder spans and where the gusset plates did not extend very near the top flange. I figured out the value of the column from end to end, and figured out the shear at the different points that would be necessary to hold that column in position. It can be figured something on the order of figuring lattice bars for a compression member. It cannot be figured with any degree of certainty, but nevertheless one can get a reasonable line on whether he is very far off or not.

Mr. Armstrong: It would be different from a column because it has no end bearing.

Mr. Reichmann: It has no end bearing, it is true, but one can assume it has end bearings. It will help guide one's judgment; that is about all.

Mr. Brunner: There is no doubt but that many girders are designed where the top flange is not nearly as strong as the bottom flange. I was present at some tests made on full-sized girders. Those girders all failed by the buckling of the top flange. They buckled at a stress of about 40,000 lb. per sq. in. We slightly reduced the bottom flange on other girder tests, and found that these girders had practically the same strength as the girders with equal flanges. I do not know that it is possible to devise a formula which will give the proper section for the top flanges under all conditions.

F. E. Davidson, M. W. S. E.: There is one point that Mr. Reichmann brought out in his paper which might be discussed more in detail, namely, the absence of data to enable engineers to accurately calculate the strength of large compression members. It has occurred to me that it would be perfectly proper for the corporations which employ Mr. Reichmann and our honored chairman, to make some tests, and thus secure the needed data to guide us in figuring the unit stresses to be used in large sections. Some one ought to do this, and who is better qualified or better equipped than the American Bridge Company or the United States Steel Corporation? The latter, in particular, being the leader in the manufacture and sale of steel in the United States, if not in the world, employing the brightest men that money can hire, having in mind the good of the general public and the economy in the use of steel, should, it seems to me, as a matter of public policy or from the attitude of a public-spirited corporation, proceed to make a series of full-sized tests on large commercial built-up sections, so that a proper formula by which to design them, may be secured.

Mr. Armstrong: In the matter of the selection of riveted or pin-connected spans for very long span bridges, I was talking with Mr. Johnson on this subject before coming here tonight. He has had some experience lately in the design of a very long span—about 370 ft., I think—in which he adopted the riveted type. I think it would interest the Society to have him tell us something about it.

Mr. Johnson: Mr. J. E. Greiner, of Baltimore, and myself, are consulting engineers for the Kentucky & Indiana Terminal R. R. Company's bridge across the Ohio river at Louisville, Kentucky. We have a series of spans from 275 to 620 ft., with a 400 ft. draw. After making quite a number of tentative designs, we finally agreed upon a double intersection riveted truss for all the spans excepting the 620 ft. Those are pin spans. We have one span 373 ft., which has a depth of 70 ft. This is a double intersection about 33 ft. panels. As Mr. Allen very well said, we cannot tell exactly what the secondary stress will be, but for that depth of truss Mr. Greiner and I concluded that the secondary stresses were from 10% to 11%, which we thought we could safely ignore with the unit stresses used. I should like to invite the Society down there later to look at it in the process of construction.

Mr. Allen: I want to confirm Mr. Johnson's statement in a small way. I have just made an investigation of some 160 ft. spans and went over the structures quite thoroughly, figuring almost every possible type to get the maximum economy from every standpoint and the best bridge we could build for the money. We adopted the double intersection type, but the second-

ary stresses are higher than Mr. Johnson found in his bridge, although we used very limber diagonals composed of built-up I-beam sections. We were able, however, to keep the fiber stresses within 25% above the allowed unit stress in every case.

Regarding another matter, I would ask if anyone has made a thorough investigation of the deflection of spans at different depths. I have an impression that the minimum deflection would be found in a span of the economical depth. When we go above that depth, the web has a decided influence upon the deflection, and if we make the depth less, the chords have the greatest influence. I had my attention called to this fact recently in the case of some trusses that were built extremely deep. I built them very deep because I wanted them very stiff, and found exactly the contrary effect; they had an excessive deflection. I then began refiguring, and while I have not made a thorough investigation, I believe that the span of economical depth, other things being equal, will show the minimum deflection.

Frederick W. Dencer, M. W. S. E.: I had one thought in mind while Mr. Reichmann was reading his paper, on saving stiffeners. Frequently we get designs in which the bolster and shoes are built up of plates and angles. In some cases there are as many as ten to twenty small stiffeners to distribute the bearing over the face plates. We find we can build these more satisfactorily by substituting cast steel bolsters or cast steel shoes, and we know that the person buying the bridge will get better results, because in the shops we cannot fit up the stiffeners and be sure to get an effectual distribution on each stiffener. So I believe for bolsters and the large bases of columns which are built up of plates and angles, that results will be better if castings are used. For the heavier loads, cast steel should be used and for lighter loads, cast iron.

Mr. Davidson: In listening to this discussion I have in mind Mr. Reichmann's premise in starting the paper, that there is a vast amount of money being spent today in structural steel in designs of all classes of buildings. Remembering that only in the monumental structures, perhaps, is a corporation or firm interested enough in the design to employ men qualified to do the designing, and knowing that there are many millions of dollars spent every year on improper design, it occurred to me that possibly it might be of interest if some of the gentlemen present who have had experience in studying wrong designs, would indicate wherein the average designer fails.

Yesterday I received a note of invitation from the president of a very large corporation doing business in Chicago to see them with reference to the design of a big manufacturing plant. In talking the matter over with the shop superintendent, I found that they had in mind a factory building covering about 200 by 700 ft. There was a big power plant in connection with it and

a number of other buildings. The superintendent told me he had had a couple of draftsmen on the pay roll for about six months and that the plant was all designed; that all they wanted was somebody to stamp the plans so they could get a building permit. I told him I could not assist him in that matter. On inquiring about the buildings in general, I found that the type was a one-story saw-tooth skylight construction, similar to Fig. 1. I believe they finally decided on 13 ft. 3 7-32 in. span. They had the brickwork figured down to sixty-fourths of an inch. The roof span was 20 ft. From the foot of the rafter of the light or open side to the center of the column was 24 in. The roof was covered with 4 in. tongued and grooved flooring, the truss spacing being 14 ft. 3 7-32 in. center to center. He said he was going to have the lumber cut in those lengths, and explained further that he had a big line shaft hanging on the bottom chord of the trusses, as well as some countershafting. I figured out roughly

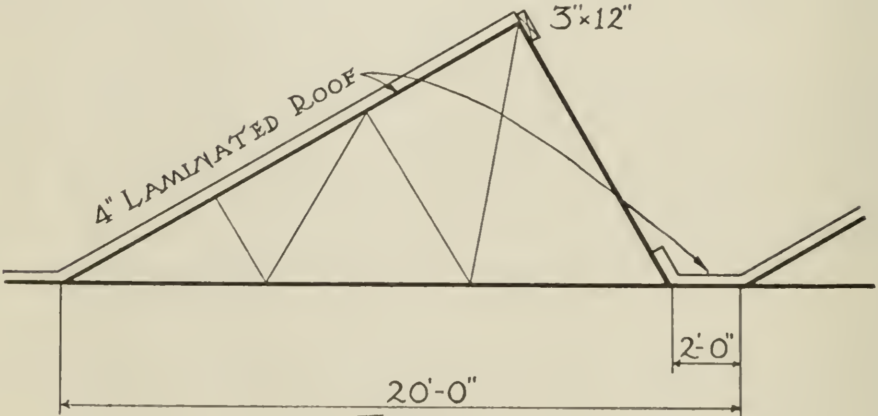

FIG. 1.

that he had approximately a three-ton load from the line shafting in addition to the live and dead load of the roof. He had his material all detailed! He had five rivets in the rafter angle connection to the bottom chord. See Fig. 2. The bottom section was marked 4 by 1½ by ¼ in.—supposed to be a channel. This illustration shows the upper section of a 6 in. I-beam column, in which the flange was coped back on both sides, and this channel section came in as shown at *C*, Fig. 2, and he had one ⅝ in. bolt to carry the end shear. Now see the absurdity of the connection. Here are five ¾ in. rivets to take that little compression of the rafter angle, and yet the end shear of the whole truss, including the load from the line shafting, had to be supported by one ⅝ in. bolt. I asked him how he was going to set the material up, and he said a carpenter would nail it up.

Here is another interesting thing. He had no method whatever of taking care of the roof water—no drainage whatever.

The roof was absolutely level and he supposed the water was going to back up and flow over somehow. I took over a design of some saw tooth trusses built by the North Works, Illinois steel Co.—some work which had been done by them for the Western Electric Co., which I knew was all right, but the superintendent said, "O, you can't tell me anything about trusses. I am going to build it that way."

Some of the employees at the steel works are going to have a chance to figure on that truss.

Mr. Robinson: The question of supporting the top chord and of providing a proper formula makes me think of a good many old girders that we have watched under service. I remember quite distinctly a series of girders on our line near Kansas

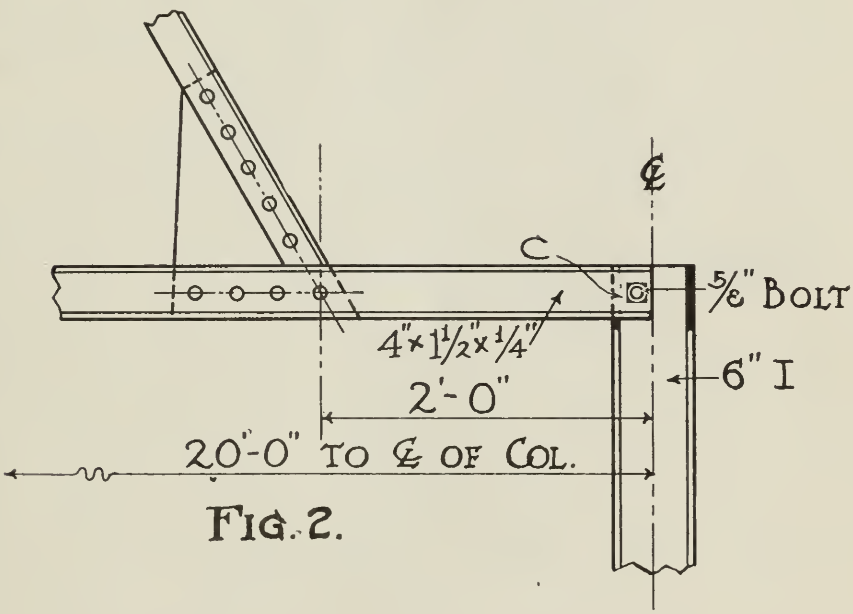

FIG. 2.

City, where we cross over the Alton and Missouri Pacific. The spans were from 80 to almost 100 ft., what they called a riveted Warren girder, with little knee braces on the inside and on the outside on top of the floor beams trying to hold the top chord in line. It was a box chord and at one time, a few years before I came on to the road, the engineers got frightened at the bridge and put on more knee braces and tried to fasten them up tight. I have stood on the end of the bridge and watched the behavior of the top chord a good many times, and it would weave around when the train was passing, just like a snake crawling or like a grape vine. That bridge stood for eight years, to my certain knowledge, under a load that was at least 90% above the one for which it was designed. Aside from weaving around and acting as though it was going to fall down the next minute there were no bad results. Nothing was broken. I have watched

many through girder spans where the top flanges were almost entirely unsupported. The knee braces or gussets sometimes would stop 3 ft. down from the flange. In other cases they would be so nearly straight up and down that they did not act sufficiently in bracing the top flange, so that these flanges would weave and twist under service. I have often wondered what would be the ultimate limit, where we could go. When Mr. Reichmann was telling us that we must get out a formula and figure these top chords, I remembered these old bridges and the number of thousands of times they have been overloaded, and how they have stood up under the service. I never knew a girder to fall down that had the top chord so scandalously overloaded, and when we are making these formulas we must take into account the experience we have had in the service of these old structures and not undertake to make them altogether too rigid. There is a possibility, I think, of making the top chords in trusses and the top flanges in girders too rigid.

Karl Hellenthal, ASSOC. W. S. E.: I do not know that I can add anything of interest, but when Mr. Allen spoke about the details of the floor-beam he sketched on the blackboard, I remembered that about 25 years ago I had occasion to take down some old bridges of the New Jersey Central. The eye-bars were, as near as I recall, between 2½ and 3 in. square. The pins varied between 2½ and 3 in. Of course, even at that time, those were quite unusual proportions between the eye-bars and pins, so I took the time to figure out what the stress in the pins would be, and found that it ran up to 175,000 or 180,000 lb. per sq. in. Gentlemen, the bridges stood; there were several of them. They had given good service for a long time, and were taken down only bcause the chief engineer of the railroad company became afraid of them. There was no particular sign of weakness, but the railroad company had just increased its engine load, and the chief engineer did not want to have those bridges carry that increased load. The pins, however, were badly worn—in some instances as much as a quarter of an inch.

I know of another bridge—a highway bridge—where the connections between the intermediate posts and the floor beams were bolted, instead of riveted as they are nowadays. The shearing stress had removed part of the bolts for fully five-eighths to three-quarters of the section—literally moved it right across—and when I figured the stresses, the number of bolts was rather scant, even under the assumption that the stress was equally distributed. About half of the bolts did not carry any stress at all because they had been shorn off. Such things make us think that some of the structures which we have built in the past stand up simply by force of habit.

Mr. Brunner: I believe the whole secret with those pins was that they were so small and so limber that they resisted the

stresses by their shearing strength instead of bending strength, and that if they had been figured for shearing strength they would have been found to have ample section.

Mr. Hellenthal: I think you are right, but if those pins were heavy enough I do not see why we make them so much larger nowadays. That is a point which might be considered in connection with Mr. Reichmann's paper. He seems to be much interested, and we all ought to be, in reducing the secondary stress. The smaller the pins are made, the smaller, of course, will be the secondary stress. If it is sufficient to proportion the pins for shear only, we might just as well reduce the secondary stress.

Mr. Brunner: In my early experience I came across a case similar to the one which Mr. Hellenthal has just described. It was the bridge on the Boston & Maine railroad near Biddeford, Maine; of the old Phoenix type; it had Phoenix columns for the top chords and Phoenix columns for end posts, and cast iron connections between the end post and top chord. In one set of pins the figured stress for bending was, as I recall it, over 180,000 lb. per sq. in. I figured the same pins for shearing strength, and found that under such assumption they were large enough. The bridge was in use for many years after without showing any sign of weakness.

Another question that should be taken into consideration in the designing of steel structures, is the initial stresses in the steel itself. If we were sure that every part of the steel would get in action at the same time under load, we could probably increase our unit stress, but as a matter of fact I believe that part of the steel has to be strained perhaps beyond the elastic limit before other parts come in action. When the material comes from the cooling beds at the rolling mill, it has to be run through the straightening rolls. That means that the material has to be strained beyond the elastic limit in order to straighten it. It is then taken to the structural shop and punched. In punching, part of the material is again strained beyond the elastic limit. After it is punched it has to be again straightened and is again strained above the elastic limit. By the time the material gets into the finished structure, part of it is in compression and part in tension from the initial stresses brought into it during the fabrication. For this reason I believe 16,000 lb. is about as high unit tension stress as we should use for ordinary structural steel.

Mr. Reichmann: I might add something about the web plates Mr. Robinson was talking about. While I do not think that our web plates are too thin to stand up under ordinary traffic conditions, I do think that if some of our large plate girders were tested to actual destruction that weakness would develop rather in the web than in the flanges. I know there have been some

beam tests made recently, and in a great many cases the first weakness appeared in the web and not in the flange of the beams, though the flange area is considerably smaller compared to the web than in the case of an ordinary plate girder bridge.

Mr. Johnson told us about his long riveted spans, but what was considered a long span a few years ago is not considered such a very long span today. I noticed his very long span was made pin connected. Of course, a 300 to 400 ft. span is a long one; yet I think that span would be perfectly safe as a riveted structure, and as far as secondary stresses are concerned, I agree with Mr. Armstrong and Mr. Johnson that we can figure secondary stresses, and perhaps our figures will be higher than the actual results will be. On the other hand, in designing structures I think we ought to try to eliminate secondary stresses as far as we can. I know of an old bridge over the Mississippi River between St. Paul and Minneapolis, which was designed, I think, by Mr. C. Shaler Smith about 1876. I think the spans were from 300 to 350 ft. long, and the top chords were made of plates and channels. The channels were 12 in. deep, the pins were in the center of the chords, and there were three ½-in. cover plates on top of these 12 in. channels. There was nothing at all on the bottom flange of the channels to balance the section. I made a critical examination of that bridge about ten years ago, prior to its being taken out. At the time that bridge was built it was figured for a train live load of 1,600 lb. per lineal foot of bridge, and at the time it was taken down the actual live loads passing over the bridge were something between 2,800 and 3,000 lb. In spite of all that, there was nothing to indicate that the structure showed any signs of weakness.

Mr. Hellenthal brought up a point about an examination which he made of a bridge, where there were bars about 2½ or 3 in. square attached to pins, and he thought that possibly we might reduce the diameter of our pins. I do not think that it would be possible under our present methods of manufacture, because the eye-bars are rolled nowadays and an eye-bar that is made of material over 2 in. in thickness decreases in strength rapidly. The material in a bar that is 2½ in. thick is much weaker than in a bar 2 in. thick, and for that raeson we must keep down the thickness of our bars. This necessarily leads us to make wide and thin bars, and we have to have a large diameter of pin in order to get the proper bearing of the metal on the pin.

Mr. Hellenthal: I do not want Mr. Reichmann to understand that I am advocating reducing the size of the pin.

Mr. Reichmann: I understood that, Mr. Hellenthal, but I just thought I would mention the matter.

Mr. Armstrong: The remark Mr. Robinson made about some old girders he had observed, which waved back and forth under

load, might give us some clue as to why these old bridges stand up so well even when we figure that they ought to fail.

It is a fact that when a bridge is properly designed, equally proportioned throughout, even though it is light, it will undoubtedly stand a much heavier load than though the main members were properly proportioned and the details weak. As we design bridges now, with the heavy loads and very heavy construction, a weak detail like that would show up much more adversely than it would in a light structure. It is a good deal like the deacon's "one-hoss-shay"; if it is equally strong in all parts, it will stand up until it goes all at once.

There are many cases where I have found bridges standing up and doing service, in which I could not figure out why they did so expect on the theory that the strains did not act as we figure, probably from the fact that the main members in deflecting relieve the points of weakness.

Mr. Johnson: I would like to ask Mr. Reichmann, if it is germane to his paper, whether he has ever investigated the proper fireproofing of columns in buildings. That is something that has interested me a great deal, and no doubt it has interested everybody who is interested in structural steel. The only way we can deal with a reinforced concrete building up to six or eight or ten stories is to get up some proper and efficient fireproofing that will be cheap enough so that the steel construction can be as cheap as reinforced concrete.

Mr. Reichmann: I have given that subject a great deal of consideration, but I cannot say that I have ever gone into the matter sufficiently to say that we have any fireproofing that is different from what is ordinarily used. The tendency seems to me to be that a lot of the smaller buildings are going to be built of concrete and steel combined, making the main columns and girders of steel, encasing the columns with concrete, and putting large reinforced concrete slabs in between the beams. That would enable rapid erection of the steel work, permit the concrete work to progress continuously and rapidly, and insure stability of the structure as a whole. In cases of reinforced concrete buildings being put up where the foundations are uncertain and there is a liability of local settlement, which would be sure to rupture the concrete girder from the column, if the main skeleton work were composed of steel, this difficulty would not be encountered. On the other hand, by using a large slab over beams that are fairly well spaced apart, some economy might be introduced, and in that way a good fireproof building could be built at a reasonable cost and put in competition with a building which is not fireproof.

THE USE OF THE GREAT LAKES.

ROBERT R. MCCORMICK.

Presented December 20, 1911.

The subject tonight belongs more correctly among the subjects of public importance than among the subjects of distinctly technical engineering. I trust that I know enough to leave the subject of technical engineering strictly alone when I am associating with men of technical training and experience. When your secretary was courteous enough to invite me to speak to this Society, I hesitated until it occurred to me that this question of paramount importance could only be distinctly understood in the lay mind when it was threshed out and brought forward through the engineering mind.

With all due respect to you, gentlemen, during my years in public life I showed that respect by deferring entirely to competent engineering authority and not attempting to set up my own judgment against technical training and experience. The public at large either has an exaggerated idea of the genius of engineering or else accepts as facts statements of any self constituted authority upon engineering matters. The present unfortunate condition of public opinion in regard to the Great Lakes is a result of this.

Some months after the subject was stated for a meeting of this Society and before this meeting, Professor Gardner Williams, of Ann Arbor, was invited to speak on the same subject before the National Irrigation Congress and did present a paper on that subject. I presume some of the gentlemen here heard him, or have read his paper. Perhaps speakers tonight will refer to it, and therefore I ask permission to introduce it here, as abstracted by the *Engineering News*:*

THE USES OF THE GREAT LAKES.**

BY GARDNER S. WILLIAMS,† M. AM. SOC. C. E.

The most commonly thought of use to which the waters of the Great Lakes have thus far been put has been in the transportation of freight. Since the days of the French voyageurs, the lakes and their connecting waters have formed a great highway of travel and commerce that early established the lines of foreign conquest, and later of national development. To aid commerce on the lakes more than $25,000,000 have been spent in deepening and improving channels in the Upper Lakes and their connecting

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†Consulting Engineer, Ann Arbor, Mich.

waters, not to mention the expenditures for lighthouses, beacons and buoys, and the deepening of harbors.

While the purpose of these improvements has been to provide deeper channels for the passage of vessels, the work has frequently proved an example of robbing Peter to pay Paul; for as sure as a channel has been deepened the flow through it has been increased, with the result that the waters above it have been lowered and frequently dredging has been necessary to maintain the former depths. The most striking instance of this is at the St. Mary's Falls Canal, where the improvements of the channels toward Lake Huron have so lowered the water at the locks that the possible draft of ships passing has already been reduced between one and two feet, and the end is not yet.

Probably the most important change on the lakes is that which has been produced on Lake Michigan as a result of the improvements in the Detroit and St. Clair rivers and through Lake St. Clair, the effects of which have been variously attributed to deficient precipitation, excessive evaporation, the cutting of forests and the Chicago Drainage Canal diversion.

Until 1888 the channels connecting the Great Lakes were in substantially a state of nature, except for the St. Clair Flats canal, opened in 1874, through the delta of the St. Clair River, and the uncompleted Limekiln Channel near the mouth of the Detroit River, which was begun in 1876 and the first cut (300 ft. wide) opened through in 1888, the channel being finally completed in 1891. Simultaneously with the opening of the Limekiln Channel in 1889 a fall was noticeable in the relative elevation of Lakes Huron and Erie, and in the six years, 1890-1895, the mean elevations of the surfaces of these lakes were 0.58 ft. nearer together than during the period 1860-89 inclusive, and 0.27 ft. nearer than during any six-year period in that time.

From 1896 to 1906 the lakes remained in nearly the same relative position, but during the four years, 1907-10, they have approached each other 0.22 ft. more. The average difference of elevation for the 21 years, 1890-1910, was 0.58 ft. less than for the 30 years, 1860-89, while for the months from April to October (inclusive) of 1911 they were 0.93 ft. nearer together than the average of the above 30-year period.

Since the water of Lakes Huron and Michigan flows through Lake Erie, any decrease of the former by excessive evaporation, deficient rainfall or diversion should reduce the level of Lake Erie in a similar amount to that by which the Michigan-Huron level is lowered, as over 95% of the water discharged from Lake Erie comes through the St. Clair River. The increase of fall in the surface of Michigan-Huron over that in Erie can be accounted for only by changes in the outlet of the former, and hence it appears that channel improvements have lowered Lakes Michigan and Huron nearly 8 ins. since 1889.

It was recently a contention of the lake-carrying interests that any lowering of the lakes was a serious detriment to navigation and hence presumably to the general welfare. On this point, however, the evidence does not seem to be all one way, though if the contention be correct the navigation interests themselves are the greatest transgressors.

Considering the question first from the standpoint of navigation, an examination of the records of accidents on the waters connecting the Great Lakes for the period from 1904 to 1908 showed that 68% were attributed wholly or in part to the influence of the current. Any lowering of Lake Huron with reference to

Lake Erie has the effect to decrease the slope of the connecting waters and therefore to reduce the current and so contributes to the safety of navigation. If Lake Huron were drawn down to the same level as Lake Erie there would be no more current in the St. Clair and Detroit rivers than now exists through the Straits of Mackinaw, where part of the year the flow is from Huron to Michigan, and part from Michigan to Huron.

From the standpoint of Chicago, if Lake Michigan were restored to its former elevation serious interference would result to the drainage and sewerage systems; lands now above water and at all times usable would be subject to submergence at intervals, and the safety of the works along the drainage canal might in places be questioned. On the other hand, a lowering of Lake Michigan would be met with rejoicing by every riparian owner along its borders. If its waters were lowered 4 ft. there would be made available a strip of land 100 ft. wide on the average around its entire circumference, and the value of the property so acquired would more than pay the cost of reproducing for navigation the depths of water now utilized.

So accustomed have the navigation interests become to feel that the Great Lakes were established for their special benefit that the foregoing suggestion is likely to be branded as the rankest heresy, and it may be worth while to digress and consider the grounds upon which the "paramount right" of navigation rests.

In prehistoric ages the only public use of waterways was for transportation. The water supply and the sewage disposal of the barbaric communities were problems of little moment. But the right of a man to float his canoe upon the lakes and streams was early recognized.

Congress by the Constitution was given authority to provide for the general welfare and under this clause has passed numerous laws confirming the rights of navigation; but with the modern centralization of population into great cities new problems have arisen, and while the railway and the highway have appeared as substitutes for the waterway, in many cases completely supplanting it, and thus demolishing the very foundation of its paramount right, new but not less paramount uses for the waters of the Great Lakes have arisen.

The cities along their borders, either directly or indirectly, are drawing from them the water needed for domestic and manufacturing purposes and while the amount so used, even in the aggregate, is relatively small and is mostly returned to the lakes again, the principle is established that this is and must continue to be the paramount use.

A further use has been found by Chicago, in the dilution and removal of its sewage, which for many years polluted its own water supply until the death rate from water-borne diseases in this city was a disgrace to civilization. At last its citizens awoke and adopted what was then considered and is still recognized to be the most feasible method of sewage disposal. At an expense of more than $65,000,000 a great canal and waterway has been constructed along the line of the ancient outlet of Lake Michigan and since its opening hundreds of lives have annually been saved among the people of Chicago and their visitors.

Time passed and the quantity of water originally diverted became insufficient to properly perform its function of safely removing the sewage of the rapidly-growing population of Chicago, and an attempt was made to utilize the further quantity needed. Then what happened? The Lake Carriers' Association, which controls

90% of the shipping of the Great Lakes (of which 90% one company engaged solely in the transportation of iron ore controls 37%), prevailed upon the United States to refuse to Chicago permission to protect the health of its 2,000,000 inhabitants, and an injunction was issued out of a United States court, restraining the city from carrying out its plans, and the case is still unsettled.

Here we have Lake Michigan, owned wholly by four states (Michigan, Wisconsin, Illinois and Indiana), through whose outlet the direction of the current can hardly be determined, and an attempt made to prohibit the citizens of those states from using the water for the highest use to which water can be put, to protect the health of man. Already, as is shown by careful and extended investigation, the water flowing in the Drainage Canal is woefully insufficient to properly dispose of the sewage it carries, and the mixture is becoming a nuisance to the communities through which it flows. But the great shipping combination at whose behest the waters of Lake Michigan have been already lowered a foot, says there must be no more diversion lest the lake be lowered an inch or two and the cargoes of ore be decreased.

It is true that freight can be carried on the lakes for a much lower cost than on our railways, but of what does the lake commerce consist? In 1910, of that passing the St. Mary's Falls Canal, 34,000,000 tons was ore bound south, 9,000,000 tons was coal generally bound north, and 7,000,000 tons was miscellaneous products, including grain and flour, or less than one-third was material in which the ordinary citizen is directly interested.

The Government has provided, without expense to the carriers, their roadbed, switches and signals and while, theoretically, these are open and free to all, practically none but the favored few can afford to avail themselves of them. At what rate might we expect our railways to carry freight if they were relieved of all expense of roadbed, switches and signals.

About $6,000,000 are estimated to be spent in improvements to navigation on the Great Lakes during the next two years. And for whose benefit? The only users of the lakes requiring deeper channels are the ore-carrying vessels. The package freighters and the passenger boats all require much less water than the present channels afford, but every citizen of the United States helps pay the bills, while the citizens of the great state of Illinois are being deprived of the right to make the best possible use of a natural resource at their doors, and the neighboring states of Missouri, Kentucky, Tennessee and Arkansas are incidentally affected to their detriment.

The use of the Great Lakes for the development of power to supply light, heat and energy to the communities along their shores is an entirely legitimate use and one that as the supply of available coal decreases, may in time become paramount, at least over navigation.

The possibility of economical power development by the present known means from the waters of the lakes is confined to the St. Mary's River, where about 170,000 horsepower (hydraulic) are available; the Niagara River, where about 7,000,000 horsepower exists, and the St. Lawrence River, where about 6,500,000 horsepower can be utilized. To correlate this power to something more tangible than mere figures, it may be said that the combined power of the above three rivers, if delivered at the wheel shaft of turbine wheels, would amount to one-fourth as much as could be obtained

> with the best engines from the coal ordinarily mined in the United States if it were all used for that purpose.
>
> Here we have a vast natural resource, one of the most valuable that nature has given to man, being absolutely wasted. The power now developed at Niagara, the "Soo" and on the St. Lawrence is only a drop in the bucket. "A mill can never grind with the water that has passed." Congress should see to it that the laws governing the use of the waters of the Great Lakes are adjusted to the requirements of the twentieth, rather than of the eighteenth century.

Even if you should be startled by some of the statements of Professor Williams,—I confess that his suggestion of lowering the level of the Great Lakes 4 ft. was so utterly at variance with my preconceived ideas as to be beyond my immediate comprehension,—even if you differ with him as to some of his facts and some of his conclusions, it is important to bear in mind that Professor Williams has approached this subject from a new point of view, the point of view of the nation. The peculiar genius of our politics in the recent decades of years, has been that it has been controlled by special privilege. I might say the genius of our legislative bodies has been the development of special privilege for the few and popular catch phrases for the many. Now, I can raise my voice and make the walls of this room ring at the iniquity of the railroads as they have been, and yet if I should do so I would be at least ten years late. The evil which existed at that time has changed. The type of man who in that day was making his fortune in the railroads has now changed his course of action, and as far as the railroads are concerned is making his fortune *out of* the railroads. Our legislation intended to correct the abuses is so far behind that the longest shot at present contemplated will fall this side of the quarry. Because of our animosity to railroads we have raised a popular cry in favor of navigation, in favor of waterways. The movement for waterways and navigation is proper enough, but it should be subjected to the same deliberation as every other public matter.

In regard to the Great Lakes, we have this peculiar condition: We have protective tariff. We put a tariff on steel in order to make the business more profitable. The tariff at the same time raises an enormous, unspendable government income. A portion of this government income is spent in cutting deep and expensive channels in the Great Lakes, the extreme depth of which is only used in the steel business, decreasing the price and the cost of steel to the manufacturer, the cost of manufactured steel not being at the same time lowered to the consumer. The price of steel rails has remained at $28.00 a ton ever since the steel trust was formed. We are accustomed to point out the Standard Oil corporation as being particularly worthy of censure because it arranged with the railroads to receive rebates not only on its own traffic but also to receive rebates on the traffic of its

competitors. In this case, we find the steel business, in the first place, protected by having its price raised by the tariff, and in the second place, we find that the income from the tariff is spent to reduce the cost of the manufacture of steel. In other words, while we protest against this kind of special benefit in one industry, through our Congress we re-enact it in another, under the veil of popular desire to regulate railroad rates. The steel magnates who control the railroads rob the roads.

Referring further to the Great Lakes and the public expenditures upon them, you have heard from Professor Williams' paper that approximately $25,000,000 have been spent in the northern passage of the Great Lakes. I was interested in looking up some of the general appropriations for harbor improvement in this country, and while I was particularly interested in the subject of the harbors of the Great Lakes, I could not avoid a temporary amusement at noticing that Galveston, Texas, has received government appropriations of $10,928,000, although substantially its entire dock frontage belongs to one concern. In other words, the government has presented one concern a voluntary present of over $10,000,000. Coming to the Great Lakes, let us read a list of the cities: Duluth, $6,600,000; Milwaukee, $2,300,000; Chicago, main harbor, $4,045,000; Calumet River, $2,700,000; Cleveland, less than half the size of Chicago, $6,600,000; Buffalo, $9,600,000. I regret that I was unable to come across the figures for Erie and Ashtabula, which are two of our steel cities. Leaving out Buffalo, which perhaps, as the gateway to the East, is entitled to special consideration in the interest of the whole country, I notice that Duluth, a small city, but a steel town, has $6,600,000; Chicago, the main harbor, a great city, but not in the steel business, having a diversified interest in its shipping, has $4,000,000; Calumet, the harbor being almost exclusively a steel harbor, $2,700,000; Cleveland, being a steel port, $6,600,000: all showing the extreme to which government appropriations on the Great Lakes have been spread for the benefit of the one particular industry.

Special privilege—I am not going to talk history and go into the form it has occupied in the past, but merely the form it is occupying in the present—special privilege seeks its strength by the stretching and warping of the laws, stretching and warping the meaning of customs. Mr. Williams has referred to the paramount right of navigation and how it is being stretched to the conclusion that it is more important to get an extra inch over a certain bar than to consider the health of communities along the Great Lakes. Special privilege has gone further than that. It has gone to the control of the voices of the government agencies. We had a report from an International Commission of Canadians and Americans on the subject of the drainage canal, and while the mouth which spoke was the mouth of the govern-

ment, the head which formulated the thought was the head of the Lake Carriers' Association.

Now I wish to defend myself from any misapprehension or any accusation of belonging to that class of speakers who are quick to attribute evil motives to the man whose conclusions he assails. I wish to state most emphatically that the greatest supporter of special privilege, the greatest supporter of the man whose business is the warping of laws, is the man whose intemperance of speech, whose disregard and abuse of the ordinary rights of man, antagonizes the public and therefore discredits all real, honest, legal reform.

The report to the general government by the International Waterways Commission was entirely wrong. The claim that the little drainage canal has lowered the level of the Great Lakes was disingenuous. No reference was made whatsoever to these enormous works referred to by Professor Williams, which have been the real cause, and no reference was made to the significant fact that the most substantial lowering of the level of the Great Lakes came after the improvement to the rivers between Lakes Michigan, Huron, and Erie and before the opening of the drainage canal.

The whole object in my being here tonight is to draw your attention to this and similar serious facts, because in recent months, while business has taken me around to various cities on the Great Lakes, I find that public opinion has been entirely poisoned, and the man on the street believes that the lowering of every inch of the particular harbor of the particular city that he lives in is due to the drainage canal. The man in all probability has never seen the flow at Niagara; he has certainly never seen the flow over the Bear Trap dam, and he takes his opinion from the agencies of the great corporation.

We have been to Washington. When I was in office I went to Washington many times to argue on the question of the Sanitary District versus the Lake Carriers' Association. The encouragement which I received was not satisfactory. The fact is that a community, like Chciago, in competition with a great special privilege industry like the steel business has not the ghost of a show. In the first place, your immediate officials, your trustees of the Sanitary District, your City Council and Mayor, would not be allowed by public opinion to keep a special agent in Washington to see at all times that their interest was fully and honestly represented, leaving out any question of the impropriety; while the great industry, of course, is always represented both in Congress and before the department.

In the second place, you are represented in Congress by nine Congressmen, in so far as they represent you, by two Senators, in so far as they represent you, and between you and a great industry it is a serious question how far they represent

you and how far the industry—not referring to any particular malevolence or malice on their part or to any particular individual, but taking men who hold political office as they run throughout the country, throughout human nature, and throughout the years. On the other hand, your special privilege is always the same organization. Its officers are practically perpetual, and when old age or death takes away the directing head he is succeeded by a man long brought up in the same interest. Your great industry runs through many congressional districts. Following the established custom—let nobody misunderstand me that I am saying induced by financial bribery—following the custom which governs the man in Congress and the man in the Legislature and the Alderman in his ward, which is that he takes care of the home industry of his district; a large corporation running through a great many congressional districts, running through a great many states, can rally to it, by the ordinary course of political custom, many times as many congressmen as can Chicago.

The reason for my being here tonight is to bring out discussion of this subject, so that we may come to a national conclusion upon the national uses of the Great Lakes. The principle which is interesting in Chicago today in future generations will probably go to many other communities which at the present time do not realize the importance of it. Law is being made, public opinion is being made.

The law of flowing streams is pretty well known to all lawyers and probably to most engineers. It is known that the law came, of course, from England, the common law of England. the small island, the place of little rivers. To stretch the theory of the rights of the riparian owner on such a stream as the River Thames or the River Tee to apply to the Great Lakes system, is not a proper interpretation of the common law. It is wrong. I am glad to say that it has not yet been established in regard to the Great Lakes, but powerful interests, backed up by strong legal talent, are dinning it into the ears of the passer-by and are forcing it upon government officials, are forcing it upon the courts, and it is incumbent upon the general public, as represented it can only be by various associations of this kind, to stand up and maintain this point, that the Great Lakes are natural phenomena unknown to the English common law, utterly apart from it, just as much as the feudal system has no right in the United States; just as much as the feudal system has been refused recognition in the state of Michigan, so the theory of the little English inland streams must be refused recognition in the system of the Great Lakes.

Professor Williams referred to the amount of power to be developed from the fall of the Great Lakes. We have come to an age where electrical power is transmitted easily a hundred

miles. In many instances electrical power is transmitted over 200 miles. I will not venture to say what is the longest electrical transmission in existence, but I have no hesitation in saying that those of us who are not taken away by unexpected death will live to see electrical power transmitted 1,000 miles; and when that time comes the electrical businesses will of necessity and by natural evolution combine into one corporation. The question of regulation of 14,000,000 horse-power, state, interstate, and international, is a subject which must not be left to wait until the nation-wide corporation has been formed. Our Canadian neighbors have met the electrical power proposition. At Niagara, through a hydraulic electric commission—they have their own transmission line—they regulate the price of power so that the producer gets a reasonable income and the consumer gets the power at a price so cheap that nobody in Chicago could believe the figures, were they quoted. Electric power can be obtained in the Province of Ontario for less than $15.00 a horse-power, 24 hours a day, 365 days a year. I can remember when the Sanitary District made a price of power of $36.00 a horse-power, that we hesitated and hesitated for fear that the price we made was unreasonably low. The price of power in Chicago, speaking on the horse-power basis, averages considerably above $100.00 per horse-power per year.

The equities and rights in the Great Lakes have got to be worked out. I do not think we will work them all out tonight. But if we make a small beginning here it may come to a great ending. But we have always got to meet two or three obstructions. One is the mainspring in politics, special privilege. Another is constitutional limitations on the power of the state. The third is a lack of a concentrating point for public opinion.

In the State of Illinois, as we all know, we have been trying for a number of years to build a short stretch of waterway at a small cost and we have not got anywhere. Why haven't we gotten anywhere? The answer is this: There have been in this controversy, two schools of thought. There has been the original school of thought of special privilege. There has been the new school of thought of the right of the government to continuously look after the rights of its citizens. The school of special privilege has its headquarters in St. Louis. Its theory of a development of a waterway is this: Government appropriations in large sums; the dockage to belong to the far-sighted man who combines business with politics and gets the practical sites in the beginning or has them already; the water power to be created the natural increment to the riparian owners. Plausible warping of facts, plausible warping of the rights of man, plausible warping of the law, the claw inside the kid glove. That point of view is not questioned in the first report of government engineers, which provided for a 14 ft. waterway, and specifically said, "This water-

way is developed so as to give the least inconvenience to the water power owners along its course," omitting to mention the apparently insignificant fact that the expenditure of public funds was to create the water power that was to be.

The other school has begun from the other direction on the theory that every dollar of property created by public taxation should belong to the body which created it. While the battle is still very much in abeyance and the end is not yet, our side is still ahead. We have the biggest water power, with the biggest head of water—the drainage canal water power at Lockport. They have two smaller powers, one in Joliet and one in Marseilles. They have the advantage, of course, that all the money they make is upon the investment of the public. The controversy from the point of view of water power exists in the northern end of our Illinois River and the Des Plaines River. The controversy in regard to the ownership of the dock sites whose value is entirely created by public funds is down at East St. Louis. The end is not yet. What value is this war on railroads, this red flag which was painted by a man now dead and is waved in the faces of all of us to create waterways, water competition, to be created by public taxation and maintained by public taxation, if each landing stage is to be in the hands of a monopoly with a real estate value for the purpose of earning interest and the purpose of being taken over by the government as a harbor terminal to a waterway created at government expense?

We have three main uses for the Great Lakes. We have the use for water commerce, we have the use for water power, and we have the use for sanitation. At the present time the public mind outside of Chicago, and certainly in Washington, is not correct. It is wrong as to the facts; it is wrong as to the theory of the law, and it must be corrected. Navigation is not of particular value, water competition is not of particular value to the people, if the terminals are to be controlled either by the same people who control the railroads or by others who will charge exorbitant rates. The development of water power is not of particular value, either at Niagara Falls or at Lockport, or at Joliet, or at the Soo, or at Montreal, if it is going to be given to a few far-sighted people with interests in politics, who will resell it at a price which is just below the cost of steam production and make enormous profits out of a public stream in which no man can, under any correct theory of the law, have any private rights.

As to the sanitary needs, the other cities around the Great Lakes have no very adequate plans, such as those of Chicago, but when the sanitary needs are fully understood, they will come to very much more importance than the value of navigation or water power; and it is not within the realm of common sense, it is not within the realm of any construction of the existing

common law or any modification thereof, that they shall be stopped for the benefit of property interests not now existing.

There are two things to contend with. The first is, allowing special privilege to do our thinking, as they have done in the matter of improving the Great Lakes. In the second place, when we realize something is wrong, we must not troop together like a wild mob and follow any general blanket remedy which is suggested, because in that case we shall be led off on another wrong track and the clever man will take advantage of it the way the ore people have taken advantage of the protest against railroads. The Great Lakes should be studied by a commission, but the commission must be one which will do its own thinking and not have its thinking offered to it.

Professor Williams has suggested the reduction of the level —I do not understand that he recommended it—about four feet. The idea is absolutely novel to me. I have been thinking along a train of thought the conclusion of which was to raise or at least maintain our present level. It has occurred to me that the Great Lakes had a particular value as a storage reservoir, with particular reference to spring floods, and I do think there have been some extravagant suggestions made, some impractical suggestions made, although the one I am about to make will hardly be classed as conservative finance or conservative engineering at this time; but I will say that there have been more extraordinary suggestions made than that a connection should be made between Lake Michigan and the Mississippi River at such a point where the Mississippi River is of higher elevation than Lake Michigan and let the great floods of the Mississippi, instead of roaring down the Mississippi Valley, tearing out the levees, washing over the land and creating havoc, be diverted into Lake Michigan —they could not raise the level an appreciable extent, and run out through the rest of the year in the low months. At least, that kind of a thing should be considered. We have grown beyond the time when we can take the country as we found it. We have grown beyond the time when one particular engineering work is sufficient for the whole country, such as, to speak in a generality, the improvement of New York harbor for the purpose of taking away all the commerce of the United States. We have grown beyond the time where any individual can carry on a work of his own, such as the improvement of the St. Clair River, without reference to the rest of the country. We have reached the point where we must think and discuss, and the more we argue at present, the more knowledge we shall gain and the more good we shall do for the consideration of the subject, the use of the water of the Great Lakes for the good of the entire nation; and for that purpose the engineers of the country would seem to be the natural originators; and the engineers of Chicago, I can hardly conceive could find a better

avocation to spend their spare moments upon than in thinking, reading up, deliberating how these great reservoirs, given by nature to this continent, which have been the playthings of individuals ever since they have been more than natural wonders, can be conserved, maintained, and used to the greatest benefit of humanity.

Discussion.

G. M. Wisner, M. W. S. E.: I have listened to Mr. McCormick's address with great interest. He has brought out a point that I have given some attention, which is that the Great Lakes have been conserved by law based on the old English laws relating to waters used for navigation and for navigation purposes only. The day has come when navigation is not as important as is sanitation and the health of the people. We can travel and transport our goods today without the aid of the Great Lakes, although in some ways lake transportation is cheaper and does control or lower freight rates by competition with the railroads.

The government has as yet failed to recognize the point which I wish to emphasize, that we need the waters of the Great Lakes for sanitation purposes and for domestic uses. The Sanitary District of Chicago today is up against the most difficult problem of properly diluting the sewage and manufacturing wastes that are going into the drainage canal. You may remember that the State of Illinois says the sewage must be diluted with so much water per unit of population. On the other hand, the government says it must not be done, and is restraining the Sanitary District from so doing by an injunction suit now being tried in the United States courts.

It is virtually admitted that 10,000 cu. ft. per sec. may be taken from the lake, which is enough under the state law to provide for a population of 3,000,000 people, but at the rate the city of Chicago and the Sanitary District has been growing, we shall have reached that population on about the year 1920. By that time we must have either devised some other method of taking care of our sewage for the excess population over 3,000,000 or we must get more water from the Great Lakes which, with the present state of public opinion, we shall not be able to do. We should have this additional water, and I think it is up to organizations of this kind to mould public opinion to the point where it will insist that the water should be used for the people and not for special privilege, as Mr. McCormick has emphasized.

The use of water from the lake at Chicago is opposed by the Niagara power interests who say the people of Chicago wish the water to develop electric power. Now, the Sanitary District does not want this water to make electric power, but, having this flow, naturally and most properly desires to conserve the energy that would otherwise waste itself over the spillways

at Lockport. The Sanitary District does not care to compete with the power companies, and as far as practicable has utilized the developed power for municipal purposes, receiving therefor only the bare cost of production.

The Sanitary District is opposed, on the other hand, by the Lake Carriers' Association which claims, and I have listened to their testimony, that by lowering the level of the lakes one inch the carrying capacity of their largest vessels is reduced, as I remember, about 80 tons, and every inch the level of the lake drops reduces the carrying capacity of each of the largest vessels 80 tons. This, of course, is at the critical points which are the St. Clair and Detroit rivers and the "Soo" locks. Then they estimate how much that 80 tons per vessel is worth to them, capitalized, and find that it runs into two or three or four millions of dollars.

Now, I say it is wrong that the navigation interests should be conserved regardless of and at the expense of the health of the people, the health of a community like Chicago, having a population of nearly one-fifteenth of that of all of the states bordering on the Great Lakes, including all of New York and Pennsylvania.

We need this water, and our right to take it should not be questioned; but it is questioned, and the result will be that, if denied the desired 4,000 cu. ft. of water, the city of Chicago must within the next ten years spend at least $20,000,000 more to take care of its sewage in a less effective manner than it would if this additional flow were available, which, according to the government's own witnesses, would lower the level of the lake possibly 2½ in.

Over in Michigan—I have heard this from many sources—the people believe, and honestly believe, that the drainage canal has lowered the level of the lakes a foot in the last year and, as a result of this belief, there is arising a demand that the drainage canal flow be shut off. It is a fact that the lake level is now a foot lower than it was a year or eighteen months ago, and it has reached lower levels during previous periodic fluctuations, but it has always returned to the higher level and will again do so.

It seems to me that we engineers should give this matter thought, and try to educate the people to the fact that the drainage canal, which is of vital importance to this community, is not doing the great damage that is claimed.

Isham Randolph, M. W. S. E.: I have read with keen interest the address of Mr. McCormick, and it has been to me as it must be to an old soldier who is taken over a battlefield on which he has fought. He hears the echo of guns he helped to serve and lives again in the midst of the storm of war.

To be guilty of an Irish bull I will say that for nearly twenty

years I have been on the firing line in this aquatic struggle. What I shall say will be largely reminiscent and historical, but will not go back to the earliest stages of the discussion over lake levels.

I do not now recall the date of the creation of the International Waterways Commission, but I know that it soon attracted the attention of the Sanitary District authorities by acts and utterances which seemed hostile to the District. In June, 1906, we were noified that a hearing would be given in Buffalo to all parties who wished to be heard in relation to the levels of the Great Lakes. This hearing took place on the 26th day of June, 1906, in the Federal Building in Buffalo, and I was sent on to represent the Sanitary District of Chicago and defend its rights as best I could.

The meeting was a depressing one to me, for I found myself friendless and in the enemy's country. The Commission was unfriendly—when I say this I mean unfriendly officially, for in spite of our official differences I had personal friends on that Commission, and I believe the official strife did not militate against personal kindness of feeling. The Canadian shipping interests were largely represented and were very hostile. Buffalo was upon its own dunghill and its opposition was bitter to the verge of brutality. The Lake Marine was there by its officers strongly arrayed against us. The President of the Lake Carriers' Association, Mr. William Livingstone, made an address which disconcerted me greatly. He said that the lowering of the lakes one inch meant to the modern Lake Carrier a loss of 100 tons carrying capacity, and that the certain lowering of the lakes six inches meant a loss of 600 tons per trip; that the average number of trips per season was 22 and the average net earning 50c per ton. Then he gave the number of vessels that would be affected and showed an aggregate annual loss of $2,500,000. I came home much disheartened; but as I ruminated on the matter it occurred to me that there was no boat on the lakes that carried 100 tons per inch of draft. I got the Blue Book of American Commerce, scheduled all of the lake boats and computed their carrying capacity and was comforted.

Shortly thereafter the then Secretary of War, Mr. Taft, issued a notice that all who were interested in the question of lake levels would be accorded a hearing before him. Of course, the Sanitary District took a hand in this. Its Attorney and its Chief Engineer prepared arguments. I had all the data collected —to refute Mr. Livingstone's statements—in manuscript, but not knowing whether I would have a chance to use it I did not have it printed with the rest of my argument. The hearing was set for January 14, 1907. I went down a couple of days ahead of time to see if I could gather any new facts that would help me. Through the help of our Congressman, James R. Mann, I se-

cured an advance copy of the report of the International Waterways Commission, and therein—sure enough—was the Livingstone address without quotation marks and therefore adopted by the Commission as its own. When my turn to address the Secretary arrived I delivered my address as far as it was printed, and paused. The Secretary addressed me thus: "Mr. Randolph, have you seen the report of the International Waterways Commission?" I replied, "Yes, Mr. Secretary, and I thank you for asking me that question, for it gives me an opportunity to call your attention to grievous misstatements in that report." Then I read as follows:

"A Review of Some Questions Raised in the Report of the International Waterways Commission.

"On page 8, paragraph 24 of the Report of the International Commission, I note a certain misleading statement into which the Commission has doubtless been betrayed by the Lake Marine Interest, as I heard the assertion upon which it is based made to the Commission in Buffalo on June 26th last, by Mr. Livingstone, President of the Lake Carriers' Association. It is this:

"'In the modern vessel each inch of increased draft adds about 100 tons to the carrying capacity.'

With this text they go on to state that:

"'To lower the water surface six inches is to reduce the capacity of the vessel about 600 tons.'

Then they reason further:

"'If the freight rate on ore be taken at 55 cents per ton, exclusive of the cost of loading and unloading, and the number of trips during the season at 22, there appears a loss of over $7,000 for the season for each vessel. The number of vessels navigating the Great Lakes which draw 19 ft. or more is 417, and their tonnage is 1,541,414 tons, which is about three-quarters of the total tonnage of the lakes. It is a conservative estimate that the loss to navigation interests resulting from a reduction of 6 in. in depth of water is $2,500,000 per annum, which, capitalized at 4%, amounts to a loss of $62,500,000.'

"This is a terrific showing—but is it true? Here is the crux of the discussion.

"I have made such a study as the sources of information available to me have admitted of and I find this: the American Lake Marine comprises the following numbers of vessels of the several gross tonnages named:

265 vessels between 1 and 2 thousand tons.
158 vessels between 2 and 3 thousand tons.
77 vessels between 3 and 4 thousand tons.

99 vessels between 4 and 5 thousand tons.
31 vessels between 5 and 6 thousand tons.
22 vessels between 6 and 7 thousand tons.

652 vessels—Total.

"At the time I heard President Livingstone make this statement, I accepted it as authoritative, but later, upon reflection, I grew skeptical and so I began to investigate and give my results:

"I found that in the American Lake Marine there were at the time he made his assertion 153 vessels, between 300 and 400 ft. long; maximum length in this class 396 ft. x 45 ft. beam; that there were 111 vessels between 400 and 500 ft. maximum length in this class of 488 ft. x 52 ft. beam; that there were 42 vessels between 500 and 600 ft. long and the maximum length of this class was 588 ft. x 58 ft. beam.

"Of the maximum in each class there were—

1—396 x 45
2—488 x 52
6—580 x 58

"For the sake of argument, let us figure all of each class as of the maximum of that class—a manifestly improper thing to do—and see what results we get:

396 by 45 gives us 41.2 tons per inch of depth.
488 by 52 gives us 59.4 tons per inch of depth.
580 by 58 gives us 78.8 tons per inch of depth.

153 vessels multiplied by 41.2 equals 7,303.6 tons.
111 vessels multiplied by 59.4 equals 6,593.4 tons.
42 vessels multiplied by 78.8 equals 3,309.6 tons.

Total....................17,206.6 tons.

for 1 in. in depth. 17,206.6 multiplied by six, gives us 103,239.6 tons for that depth. Multiply 103,239.6 by 22 trips and we get 2,271,271.2 tons as the year's loss of tonnage. This at 55 c. amounts to $1,249,199.16. Capitalize this sum at 4 per cent and we get $31,229,979 instead of $62,500,000. Now let us try the inaccurate but approximately reasonable method of taking for these vessels an average between their maximum and minimum dimensions and see where we come out.

153 vessels 348 x 48 equal to 39.1 tons each per inch, or 5,982.3 tons.
111 vessels 444 x 48 equal to 47.3 tons each per inch, or 5,250.3 tons.
42 vessels 540 x 56 equal to 70.8 tons each per inch, or 2,973.6 tons.

14,206.2 total tons for one inch in depth. ,
14,206.2 multiplied by six (inches), equals 85,237.2 tons.
85,237.2 multiplied by 22 (trips), equals 1,875,218.4 tons, which, at 55 c. amounts to $1,031,307.12, which sum capitalized at 4% amounts to $25,784,253, a considerable saving over $62,500,000.

"It is proper before leaving this subject, to state that at least one vessel 600 ft. long and 58 ft. wide has been launched by the Chicago Ship Building Company, and the same company is now building one 605 ft. long by 60 ft. beam. The tonnage per inch of depth of the first is 81.5 and of the second 85 tons. There is now a vessel in sight on the lakes having a carrying capacity of 100 tons per inch.

"But why discuss any such proposition at all in view of the report of a Board of Government Engineers that remedial works at the east end of Lake Erie will restore navigable depths at a cost of only $796,923; and when further it is demonstrable that a proper control of the waters of Lake Superior by works now installed, will remedy the whole evil? It may be urged that the existing works are inadequate, but it cannot be denied that they can be made adequate by a very inconsiderable additional expenditure.

"As to the propriety of Canadian and United States governmental advice to a city in any State of this Union, as to the manner in which it shall dispose of its sewage and conduct its municipal engineering, I must leave the people of the several States to express their opinions.

"(signed) Isham Randolph.

"Washington, D. C.,
"January 12, 1907."

When I finished reading, the Vice-President of the Lake Carriers' Association demanded that I withdraw the statement. I asked why I should. He replied, "because you are a civil engineer and don't know how to figure lake tonnage." I asked how they figured it, and not one of them could tell me. I wrote out the formula and gave it to General Ernst, who sat beside Mr. Taft, asking him if it was right. He examined it and said it was right. Then Harvey D. Goulder, attorney for the Lake Carriers, came over and asked me to withdraw the report. I asked, why? He said, "Your sources of information are incorrect." I showed him the book from which I got it. He said, "That is authentic," and sat down.

I have my copy of that report of the International Waterways Commission, but it is a rare document. It was recalled and expurgated before re-issue. There is a lot more history in this connection that is liable to be lost, but I take it that the

Journal of the Western Society of Engineers has not undertaken to become the repository of historical reminiscences. The effect of the improvement of the St. Clair and Detroit rivers upon outflow from Michigan-Huron is shown unequivocally in U. S. Government reports. First I will quote from the report of the "Board of Engineers appointed to report on Deep Waterways between the Great Lakes and Atlantic tide waters." This report is Document No. 149, 56th Congress, second session. On pages 297-298 is this statement: "The low water level of Lakes Michigan and Huron has been lowered about 1 ft. during the past 13 years by the natural and artificial deepening of the St. Clair and Detroit rivers." On page 277 of this report the discharge through the St. Clair river is given as 190,000 c. f. s. This report was transmitted by its authors June 30th, 1900. Since then the work of the U. S. Government in deepening the intervening channels and depleting the lakes has gone bravely on, as is evidenced by the reports of the U. S. Lake Survey. The 1905 report gives a discharge of 206,400 c. f. s., with Lake Huron at elevation 581.40. Six years later, the 1911 report, shows a discharge of 210,000 c. f. s., with Lake Huron at elevation 581.28. The missing link in this progressive demonstration is the elevation of Lake Huron at which the discharge of 190,000 c. f. s. was determined; but the end is not yet. Deeper and wider channels are in progress of construction and lower levels will be reached and an uninformed public will charge it all to the Sanitary District of Chicago. There is a question for our Congress to settle and it will never be settled until it is settled right; *Which is the higher function of any natural resource, the earning of money for great corporations, with that earning predicated upon an expenditure of the people's money*—or the saving of human life, the conservation of the health of the people which the Congress is created to protect?

President Chamberlain: We have with us one of the trustees of the Sanitary District, Mr. Sullivan. We shall be glad to hear from him.

Mr. Thomas M. Sullivan: I cannot say that I came here tonight to indulge in any remarks. Rather, I came here as a listener. I was much interested, however, in the remarks of Mr. McCormick, and I agree with him very largely that the great problem for the people who are asking for the use of the water from the Great Lakes is the molding of public opinion in favor of the modern uses of the water. I believe that the people in large cities who reside along the Great Lakes are entitled to the use of the water for drinking purposes and for sanitation, just as freely as we should be to the air that we breathe.

I was much interested in one suggestion which Mr. McCormick made—a new one to me, and I think worthy of con-

sideration—and that is that Lake Michigan should be made the storehouse for the waters of the Mississippi. I think that is a problem that could be worked out, and I cannot see any reason now, it being a new thought to me, but that it would be a legitimate use for the waters of the great river, the Mississippi, and also be of material benefit to the people of the Great Lakes.

I have always thought that the problem of conserving the waters of Lake Michigan is more particularly a problem for the people of Chicago. Lake Michigan, to my notion, should not be specifically considered one of the Great Lakes. It is surrounded entirely by the states of this country, and that the international commission should take the waters of this lake specifically under its care and legislate for it the same as it does the other lakes comprising the great chain of lakes, is somewhat foreign to my mode of thinking. I think, as Mr. McCormick and Mr. Wisner said, that the use of water in our Great Lakes is tending and must necessarily tend to its use in sanitation for large cities on the lakes. Navigation is declining in importance in comparison with the use of the water in the future for proper sanitation and the health of the people who are living along the lake.

I am not one of those who believe, however, that Chicago and the Sanitary District will be estopped from taking more than 10,000 cu. ft. of water from the Great Lakes if occasion requires a greater flow of water, and I believe all that is necessary for Chicago to obtain all the water needed to properly dilute its sewage is a healthy public opinion, and I am glad that meetings of this kind are organized for that purpose. I believe that it could be initiated here, and with a little proper effort on the part of societies like this, composed largely of engineers who are conversant with these great works, that we will eventually get from the government permission to use such waters as we shall need for a great many years properly to dilute the sewage of this city, and, of course, everybody will agree that the dilution of sewage is the most economical and, in fact, the best method known to us at present.

President Chamberlin: While we are on this question of sanitation, I would say that we are fortunate in having with us this evening a gentleman who has labored very hard in this community for the health of the community, I know we should all be delighted to hear from Dr. Evans this evening.

Dr. W. A. Evans: I had not expected to speak and in consequence have nothing arranged, even in my own mind. I followed with great interest what Mr. McCormick had to say and it suggested to my mind a great many thoughts that were entirely new to me.

I think the only thing on which I could in any way enlighten you is the condition of the water in the Great Lakes.

We have an idea that this great mass of water is so pure and, at the same time, so massive in its proportions that it will stand a great deal of abuse and that the day is not anywhere near at hand when it will become unfit for drinking purposes. The water of all of the lakes is low in organic matter, and low in mineral content. There is no mineral substance which has been found in the lakes that is suggestive of pollution, except a high chlorine content for Lakes Huron and Erie and Ontario. The general explanation of that, however, is that it does not come from urine contamination or decomposing organic matter, but that it probably comes from salt derived from salt lakes and may be from salt seepage at the upper end of Lake Michigan and possibly at the western end of Lake Superior. There is a fairly large oxygen content in the different waters of these lakes. There is a relatively low bacterial content, so far as the general body of the lakes is concerned. However, if we interpret this as meaning that the various places where people are congregating together are having waters that are pure and free from contamination, we are guilty of an interpretation which is not justified by the facts. Or, in other words, instead of drawing conclusions from the conditions of the waters as they are found at large and average conditions that prevail in the area far from sources of supply, if we draw our conclusions from the typhoid conditions that prevail along these lakes, we find that every community is suffering from time to time from water-borne typhoid. There have been water-borne epidemics of typhoid fever at Buffalo that are of great significance; also at Erie. At the present time they are in the midst of one at Cleveland. We have had water-borne typhoid at all of the points located at the foot of Lake Michigan. Milwaukee in 1909 and 1910 had a water-borne epidemic of typhoid fever that was of much consequence to that community. Probably the cities along the south shore of Lake Superior have had rather more dramatic typhoid epidemics, water-borne in character, than the other cities to which I have alluded. We are having a water-borne epidemic of typhoid fever in the cities of the lake shore north of Chicago at the present time. The investigations of the Lake Michigan Water Commission have demonstrated quite conclusively that to the south of us there is pollution of the water within seven miles of the shore that exists practically all of the time, and that the water intakes of that district are located in waters that are almost habitually polluted. This constitutes a serious condition of affairs, and means that however great the volume of the water may be and however rich it may be in oxygen, and however free it may be from organic matter, it is not purifying enough in its capacity to take care of the pollution that is being poured into it in proximity to centers of population, wherever they may be located. All this means that we

have to have a much more comprehensive study made of Lake Michigan as a source of water supply, of the Great Lakes as sources of water supply, than we have ever had made in times past; that the basis on which we have proceeded in taking water from Lake Michigan for the purposes of watering our people and the putting of sewage into the lakes by all of the states located on the lakes, is not one that practical experience has justified as being safe. We must take into account certain factors which have not heretofore been considered. Various cities are applying temporary expedients even at the present time. Milwaukee has been chlorating its water for more than a year, and Cleveland is now doing it. There are certain practical reasons why this is not working out to entire satisfaction as a temporary expedient; but even as a temporary expedient it is, of course, to be recognized as having no bearing at all upon the ultimate solution of the water problem of these cities.

There is another angle to the matter, and that is this: that the shipping itself shows an utter disregard of the sanitary rights of the cities. Commonly the vessels that ply the lakes steer by the intake cribs as their guiding points and pass in close proximity thereto. Quite a good deal of sewage is discharged from the ships, for I know of no ships which are constructed so as to make such disposition of their sewage as is necessary for the protection of the waters in the vicinity of the place where the ship is lying. Fortunately, or rather let us say from the standpoint of justice, there is a sort of poetic justice in the fact that they suffer more from polluted water than do the towns at which they touch. The statistics show that the sailors who are manning the ships on the Great Lakes suffer from a higher typhoid rate than do the people of the communities located on the Great Lakes, or the people of the communities from which those sailors are drawn. There are some reasons for this. They have shown no regard for the rights of the people to whose intakes they pass in close proximity. They have shown just about as little regard for the sanitary rights of the people who are on those ships. Occasionally they have taken in harbor water in the harbors in which they were lying and have filled their tanks with such water. More frequently, however, they have waited until they have gotten out into pure waters before filling their tanks. The water is then sucked in through sea-cocks and several feet of polluted water is drawn in before the pure water is reached. Of course, that is sufficient to pollute the water in the tanks. Toronto now requires that ships which make that port shall fill their tanks from the city water mains.

There is a certain amount of water-borne typhoid in all of the towns that are located on the Great Lakes, and occasionally there is a flare-up, and there is a parallel in this with the conditions that prevail on the ships. There is an average amount of

typhoid amongst the sailors on those ships in excess of the average amount of typhoid in towns located on the lakes, and occasionally they have a flare-up on them, a water-borne epidemic of typhoid fever limited to certain lines or limited to certain boats.

Our condition in Chicago is this: We have about twenty-two miles of Lake Michigan where there is no pollution, except a certain amount of shore wash. We have an intake on the north, one on the south, located within easy reach of flow of pollution from communities discharging polluted water into the lake to the north of us and to the south of us, respectively. It has been demonstrated that typhoid bacilli in tap water drawn from Lake Michigan will live about seven days. Experiments indicate that in water relatively free from organic pollution they will not live to exceed thirty days. In all probability the typhoid bacilli that flow into Lake Michigan from the mouth of the Calumet River would die out in less than seven days. But if the wind blows steadily from the mouth of the Calumet River to the Sixty-eighth street intake, there will be typhoid bacilli that have gotten into the lake, and occasionally some from the Calumet River will reach the Sixty-eighth street intake before they die out, flow through the mains, and reach the taps of the people in the district south of Thirty-ninth street. The water from the Sixty-eighth street intake is frequently found polluted, as shown by the examination for the *colon bacillus.* I do not think there is any question whatsoever, but that we can predict—at some time to be determined by accident or chance, but some time not far off—a water-borne epidemic of typhoid fever in the Hyde Park district just as the typhoid epidemic of the North Shore has been predicted more than once, just as the typhoid epidemic of Hammond and Whiting and that group of towns has been predicted. Just when it will come I do not know. It depends upon accident, chance, but that it will come unless some change is made, I think there is no question at all.

All this, to my mind, amounts to this: That so far as the use of the waters of the lake for the purposes of disposal of sewage and for furnishing drinking water is concerned, we have about come to the breaking point. We have pushed them about as far as they can be pushed, and we in Chicago are suffering rather less than the other places that are located on the lake. They are quite at the breaking point and we are somewhat near to it.

President Chamberlain: I do not know that we have any representatives of the navigation interests with us this evening. I know there are some of the people representing the electric power producers, but before calling on any of them I would like to call on Mr. L. K. Sherman, engineer of the Sanitary District.

L. K. Sherman, M. W. S. E.: I want to bear out one of the points that Mr. McCormick brought up, in regard to the report of the International Waterways Commission. In their report, if any one looks it over casually he will get the idea that it is impossible to regulate the surface of the Great Lakes. They emphasize this and they illustrate it in a number of instances. They say that the surface elevation of the lakes cannot be fixed between certain limits. However, on looking through that report a little closer, we come to this:

"It does not follow that nothing advantageous can be done to improve or maintain the level of the lakes. It is possible to raise the level of any lake by simply reducing the size of the outlet. If the level in the lake has been lowered, by the diversion of the drainage canal or by enlargement of the outlets, the remedy seems to be in compensating works rather than regulating works."

By compensating works it means that a dike can be placed in either the Niagara or St. Clair River. These dikes or dams would compensate for the entire amount of lowering that would be caused by a flow of 10,000 or even 14,000 ft. The government estimates this lowering at respectively 6 in. and 8 in. These dikes are nothing more than submerged dams, or, in the case of the St. Clair River, it would be a dike paralleling the shore and contracting in certain places the channel of that stream. The fluctuation would go on just the same, but the minimum stage of the lake would be kept so that it would offset these few inches of lowering. The cost of such works would be small compared to the result. It seems to me that this is an important point. Who should pay for the cost of these dikes or works to regulate the level of the Great Lakes, assuming that such is necessary? Personally, I think these few inches of lowering do not amount to anything. But granting that it is important, it might be said, "Why, Chicago is using this 14,000 ft. of water, it is their business to pay for the compensating works." It is not. The 14,000 cu. ft. of water would be used not simply by the Sanitary District of Chicago. It is available for the entire State of Illinois, the entire Mississippi Valley, for sanitation, navigation, and for water power, which are of as great value as any navigation that would exist on the Great Lakes. If government officials, hidebound by past precedent, are cautious about granting a flow of 14,000 ft. to the Sanitary District, and if courts, which are narrowly bound and must be bound by precedent, are unable to grant the highest and best use of the Great Lakes, then, gentlemen, we are on the right track in proceeding as we are now doing to make agitation which will result in legislative action and bring the uses of the Great Lakes up-to-date.

President Chamberlain: We have with us a representative

of one of our great electric power producing corporations. I do not know whether this corporation is directly interested in the production of power from the Sanitary Canal and Desplaines River, but I judge from my experience with some of these electric power companies that there is a community of interest, we might say, and I presume that Mr. Abbott can tell us something of interest in regard to the production of hydroelectric power.

W. L. Abbott, M. W. S. E.: This problem, "The Use of the Great Lakes," is one to which I have never given any study. I have, however, heard it discussed by such engineers of national reputation as Messrs. Cooley, Randolph and others, and have considered the solution of the problem a subject for those who have made a special study of it, as apparently the speaker of the evening has.

After listening to the very interesting talk this evening, I must confess that I am somewhat at a loss to apply the speaker's remarks to the subject of the address. I gather, however, that we should not develop the navigable features of our lakes for fear that it may be of benefit to the steel industry, that we should be careful how we develop the water powers of the Great Lakes for fear that it may be of benefit to the electrical industry, and that one of the great objections to developing the tributary canal and river navigations is that such development may be of benefit to the owner of dock and riparian rights along the way. I also infer that the development of these waterways would be a simpler matter were it possible to take private property along the way without proper compensation.

The paper of Professor Williams, which has been quoted here, proposes that the water level of the lakes be drawn down four feet or thereabouts, for the purpose of providing a greater flow in the lake outlets. I can understand that so long as the level is being drawn down a greater flow will be available, but after the level has once been reduced to the allowable minimum there will be no more flow than was formerly available, and the sills of all the harbors will then be that much nearer the surface.

The proposition to use Lake Michigan as a storage basin, to accommodate the overflow of the upper Mississippi River, is a bold one, but I fail to hear it seconded by Dr. Evans. The reason, I assume, is that it would interfere somewhat with his plans for preventing pollution of the lake waters. Neither did I hear Mr. Wisner second the proposition, the reason in his case being, I presume, that he does not see how it would be possible to bring that water across the intervening highlands and water courses. It is my opinion that the flow of the upper Mississippi is a comparatively negligible matter in the river basin below the mouth of the Illinois, the Missouri, the Ohio,

and other tributaries lower down where the great damage is done by the Mississippi floods.

President Chamberlain: We have with us an engineer, a hydraulic engineer, whom we all know and whom we are all proud to have with us; one who, I believe, has probably looked at this question of the use of the Great Lakes from all sides. I wish now to call upon Mr. Lyman E. Cooley to discuss this question.

Lyman E. Cooley, M. W. S. E.: This is an interesting and important subject, and as I shall probably have occasion to discuss that matter in connection with the deep waterway in the course of the coming year, I will speak on only one or two points this evening.

I sympathize with the motives of the leading speaker and those who have followed him. I agree with his general attitude without fully agreeing with the diagnosis, or the reason, perhaps.

On the question of ownership of public utilities, and especially future water power, I think I gave my views quite fully in an address at the Annual Meeting of the Society in 1906. On that point and some others I fully agree with the speaker. We should safeguard in advance rather than make a stern chase later, which is usually futile.

I was connected with this lake level question 27 years ago and gave it at that time an original investigation which satisfied me—and I believe it did all parties at that time—in regard to the questions involved in the securing and passing of the Chicago drainage law. We did not then have all the data that we now have, but I do not know that the more exact data have materially changed any point of view that we then held. We are bound to admit that the lake level will be lowered by taking out water. How much, is a matter that will always remain in doubt, a matter which can never be determined practically and which can only be inferred from an academic discussion. We know that the amount of that lowering is almost negligible compared to the other fluctuations which occur through difference in rainfall,—not only in different years, but even monthly, weekly, and daily—from changes of wind, changes in barometer, and other causes. In 1819 the lakes were the lowest ever known in the history of the Great Lakes—a foot lower than they have ever gone since—at a time when man had made no impression upon the water-sheds of the Great Lakes and no improvement of them. In 1838 the lakes went higher than they were ever known to have gone before or since. In fact, the French records at Detroit indicate that the water has not been higher in 200 years. The entire range was about 6½ ft. between those dates. We have had, apparently, changes in

the base levels, such as occurred about 1889 in the levels of Lakes Michigan and Huron, by which these lakes were lowered from 6 in. to 1 ft. The cause assigned is probably correct, the changes occurring in the outlet at Port Huron, although there is room for difference of opinion in regard to that, in view of what occurred in 1819 and again in 1838. In any event, it is not a subject which should engage the attention which it has engaged, nor which should excite the apprehension and comment which it has excited. The matter is not a question of taking the water or the right to take the water. That is clearly within legislative power to appropriate, both in State and in Nation, like any other part of the public domain. The question should be the remedy, if a remedy there need be, and there are a number of remedies.

It is admitted by everybody with more or less discussion and more or less reservation, that we can control the level of the lakes. The cheapest remedy, probably, if remedy there is to be, is to deepen the channels of the lakes—put them down. I somewhat sympathize with Mr. Williams' view of lowering the levels of the lakes and have made that suggestion myself on former occasions; in fact, I think I am on record in the past 27 years on about all the suggestions that can be made. Lowering the lakes and maintaining their levels two or three ft, lower would be of enormous advantage to every city around the Great Lakes from a sanitary standpoint. To all these cities located around the mouths of creeks, which have been filled in and raised up like the city of Chicago, to lower the lakes two or three feet would be an advantage, in comparison with which the cost of deepening the channels of the lakes and deepening the harbors would be a bagatelle; so I am inclined to take the view that the best remedy would be to lower the level of the lakes. This matter was before the committee of Congress in 1910. I discussed it before the house committee and also before the senate committee where Mr. Burton raised the question, I then took the position that if the matter was to be remedied there were at least four ways in which it could be remedied, including that of diverting the head waters of streams. There are many thousand square miles of territory the drainage of which can be diverted into the Great Lakes without extraordinary cost; for example, the head waters of the Ohio and the Mississippi Rivers, which would compensate many times for any volume of water taken out. I am not suggesting this as the best remedy. I am suggesting it as one of the possibilities. I expressed the view, which I thought the committees of both houses of Congress sympathized with, that the Great Lakes were natural reservoirs to be appropriated and used for conservation, as we actually build artificial reservoirs and appropriate the waters and use them where there is any reason to do so. I will

say, as long as we are on this conservation movement—and I think it has come to stay and become a part of the public policy, growing public policy—I see no reason why we should not make a beginning in the idea that the reservoirs of the lakes are to be taken advantage of as natural reservoirs, for the storage of waters, and the use of such waters in any direction that we choose and for any purpose that can be justified. I sympathize with the object of this meeting if it results in giving any strength or cognizance to such a policy, or such an idea.

But to go back a little in the history of the proposition, to the time when we began with these things, about 25 or 27 years ago. We were a little tender on the sanitary side of this question. It was then considered that the wholesale taking of water for sanitation might be in the nature of private use. We were decidedly tender on the water power side of the question, but it was thought that if we could justify the taking of these waters for the creation of a deep waterway to the Gulf of Mexico, that that would stand. Therefore you have that theory in the State legislation and in the law by the advice of the most eminent counsel then in the city of Chicago and State of Illinois. That is one reason for the waterway point of view in the drainage law and still the main one in sight, although the sanitary view as a reason has grown.

Without going into that at any length, I wish to call attention to the situation. The executive departments of the government have been somewhat querulous ever since the matter started. There was, in fact, no action adverse to any right of the State of Illinois or the Sanitary District to taking the water, at any time. We had actually constructed the main channel and were about to open it in 1899, when there was passed a Section of the River and Harbor Act, which delegated to the Secretary of War and the Chief of Engineers the control over all navigable waters and any interference therewith. It was a negative act, prohibiting any interference whatever without their prior consent. I held then and still hold that we had completed the work substantially and we are entitled to the use of the channel we had actually built, having a capacity of 14,000 second feet. The executive departments have not chosen to grant that. What they would do in the case of an actual ability to use that capacity through the completion of feeding channels I am not able to say. The reserve power in the premises lies with Congress, the legislative body. All the permits we have had, all the permits we are ever likely to get from the executive department, are revocable permits and we must go to that legislative power sooner or later. I am in favor of going to it just as soon as we complete the steps in the program which are now pending. We have to have, in my judgment, or ought to have prior to that, two or three basal decisions in the courts. We

have had one basal decision which I regard as vital. That was in the case of the State of Missouri against the State of Illinois and the Sanitary District, decided in 1906, in which, in the last two or three paragraphs of the opinion of the Supreme Court of the United States, it was held that by legislation of the United States, passed in 1822 and 1827, and appropriate legislation by the State of Illinois, a new outlet had been created to the Great Lakes, and the right of Chicago in that outlet and of all the cities of Illinois in it was just the same as though it had been a natural river. As to how large that outlet should be is a question as to the use to which it shall be put. There is a very decided squint bythe court in our direction, as I see it.

There have been decisions later in the New Jersey case and in the Maine case, which to me are very significant, which go far, in my judgment, to wipe out the old doctrine of riparian rights, which the first speaker has referred to. Unfortunately, the decisions in our own State, even of our Supreme Court, go to the other extreme. We have now going on in the Federal Courts, and also on appeal from the State Courts, cases which will test, and I hope settle for the whole United States the question of what constitutes a navigable stream and what are the people's rights in the same. We hope to get a basic decision of it and I think we will get that. The attitude of the Attorney General of the United States is such that I think we will get a final decision in the matter during the coming year. This other case that I referred to, seems to be delayed for some reason or other. I had hoped to see that pushed to a speedy conclusion. That is the injunction case which has been referred to, I think by Mr. Wisner, as the Calumet case. There is a point in that with reference to the rights of the State of Illinois to appropriate waters, which I would like to see disposed of. When these basic decisions have been rendered, I think we will be in better shape to take up our matter with the courts. It may be that we will get out of these cases all that we desire. Whether we do or not, it does not destroy our chances with the legislative power. It may better them, even, because it is admitted that the waters can be appropriated by the legislative act, and in my judgment when the issue is presented and we are up to the time when we can furnish ample and sufficient reason that we can get legislative sanction for any volume of water that we need or any volume of water that is justified for sanitation and the deep waterway. I do not sympathize with the point of view that has been expressed that we need to sacrifice any interests in navigation, even though they be those of the steel company or any other corporation. I think that every interest which can enjoy the Great Lakes can be adequately conserved while obtaining whatever we seek in our own behalf, and I believe that when the matter is fully

rounded up and we can bring together the commercial interests of the lakes and the Mississippi Valley, not only will we get these waters to the extent of 14,000 cubic feet, but will very soon realize that we can make a still larger use of the Great Lakes to very great advantage. All we need to do is to persist in our point of view and insist upon it and reason it out with our opponents on every occasion, and I believe we will win.

President Chamberlain: Mr. Bement, we shall be glad to hear from you if you care to take part in the discussion.

A. Bement, M. W. S. E.: What I would say has no reference to any feature of the subject that has been presented, although it is of special significance as bearing on the title of the paper, as it concerns one phase of the proper use of the lakes. I refer to the matter of the deposit of dredgings and other waste material in the lake. It was the original desire that a comprehensive paper, dealing with this matter, be prepared for presentation before and discussion by the Society. The matter, however, took, instead, the form of the presentation we have had tonight.

It has seemed to me for a long time that it is not only a crime to dump dredgings from the river and waste material from the city in the lake, but, as Mr. McCormick said at one time, it is a waste of good material. I wish very much that the Society could do something to help the agitation for a discontinuance of this practice and a utilization of the material in filling in the various places on the lake front that have been mentioned for different purposes—parks, boulevards, and bathing beaches. For a number of years we have had a place on the north shore—an extension of Lincoln Park—where any amount of material could have been, and can now be, landed at a reasonable cost, saving the pollution of the water supply and aiding in making valuable land.

The accompanying map* shows the present and prospective extensions of this park. The present extension affords now, and has afforded for a long time, a more sanitary dumping ground than the one out in the lake, and one, too, more accessible. From a sanitary standpoint, dumping inshore is better than dumping beyond the water intake cribs, because if beyond, the prevailing current tends to carry the refuse to the cribs. If inshore, the floating matter would be carried into the river and down the drainage canal.

H. S. Baker, M. W. S. E.: I have listened with great interest to Mr. McCormick's paper. During this discussion I have had in mind especially the point which Mr. Bement brought up, of the use of the Great Lakes as a dumping ground, which does not seem to be at all consistent with the other uses to which we are putting it, namely for a supply of pure water. Everybody recognizes that the only advantage of dumping dredgings far

*Plate I.

out in the lake is that it is a cheap way of disposing of material, and under the Mann Act, under which all this dumping is done at the present time, dredgings may be placed in the lake at least eight miles from shore or behind closed breakwaters along the shore. At present, as Mr. Bement mentioned, there is a disposal area at Lincoln Park where some of this material is being placed. I hope that within a short time all of the dredgings from the city can be disposed of in connection with the proposed harbor work and the extension of the park to the south, as it is proposed now by the South Park Board, behind closed breakwaters along the shore. At the present time we have under discussion with the Lincoln Park officials the matter of temporarily arranging to dispose of all dredgings at the Lincoln Park extension. They are building an extension of their breakwaters north now about 1,000 ft., and there is an area in the proposed yacht harbor which they keep dredged out where I hope we shall be able to arrange temporarily to dispose of practically everything, until such time as the harbor and the south parks can take everything. The matter is being actively worked on and the park commissioners are preparing a map showing the area where our dredgings can be disposed of.

Any disposition of dredgings far out in the lake is dangerous. The ordinances require that an inspector shall be on every tug that tows material into the lake, and this is being enforced at the present time. The dumping ground is marked by a buoy, which is lighted at night and has a bell. We are doing the best that can be done now to enforce the laws, concerning dumping, but even when they are enforced there is a certain proportion of floating material that gets into the scows, especially at the disposal stations. When the wind is right it is brought back to the cribs, especially the four-mile crib, and accumulates in considerable quantities on the screens, until it is taken out. Of course, where there is floating material the screens of the cribs will not prevent the bacteria and fine pollution from passing directly into the water supply. So I am firmly of the belief and hope that we can accomplish the result of keeping all dredgings away from the actual area from where the water supply is taken, and that within a short time.

Mr. Sullivan: I am glad that Dr. Evans brought up the question of the passenger boats leaving and arriving at the port of Chicago, as to the nuisance that they are creating in the lake. It is a fact that at times during the summer there are as many people riding on some of these boats as reside in a small city or town. Last week the Sanitary District Board prepared a document and was in hopes of laying it before the Secretary of War. We had an appointment with him in Washington, but for some reason or other the engagement was postponed until about the middle of January and at that time we are in hopes of having

the Secretary of War, if he finds it within his power to do so, make regulations by which human excreta from these vessels may be taken care of in a different way from what it has been in the past.

Closure.

The Author: Our meeting has been successful to this extent, that we have stimulated discussion. From my own point of view, I wish there had been elements here who would have given more spice to it. Perhaps a sense of courtesy towards this meeting prevented me from putting a little acrimony into it myself. Not that I have any feelings of that kind, but what we need is noise, noise to go outside of the four walls of this building, noise which will reach into other states. I do not magnify the facts at all when I say that if all the conditions which Mr. Cooley and I both look forward to had taken place and we went to Congress with a bill, I do not believe it would receive five votes outside of the Illinois delegation. I make that as a statement of opinion—it cannot be made a statement of fact—which has come to me through meeting as many as I have of the residents of other cities on the lake and meeting their firm conviction that the present height or the present lowness of the lake is due to the Chicago Drainage Canal, and that Chicago is finding a cheap way of benefiting itself at the expense of the country. That impression, I wish to say further, has been deliberately fostered.

It seems that I did not succeed in making my impressions, my views, clear to all the members, and it is due to me that I should elucidate them before I go.

In the first place, as to any feeling of hostility toward the United States Steel Corporation, that I did not wish that company to have the full use of the lakes or did not wish them to be better improved if thereby the steel company would be benefited. I have owned stock in the United States Steel Company since 1903, and, unlike the directors and owners of it, I have not gambled with it, but have held it all that time. I do not wish to see my stock damaged unnecessarily. At the same time, my property interest or my business interest is not sufficient to make me anxious to see and willing to see the United States Steel Company impose upon this nation in any particular. The fact that I stated is this: That the steel company, in the first place, is the beneficiary of a large protective tariff, which protective tariff in turn brings in a large revenue, which in turn is spent to reduce the cost of steel, and the price of steel has not been reduced. The steel company, furthermore, objects to the city of Chicago taking the best method of protecting the life of its citizens because it is thought that perhaps that will lower the level of the lakes one inch, thereby reduce the cargo of the

steel boats 80 tons apiece, and by a process of bookkeeping may cost the steel company money. The steel company is picked out on this occasion as an illustration. The other users of ships on the Great Lakes are guilty in less degree.

Second, that I do not want the power developed at Niagara Falls for fear that it may benefit the power companies. We will not read the record, but I am sure there is nothing which I said which could bear out such a statement. It is my own belief that all the water power between Lake Erie and Lake Ontario should be developed into electric water power. I do not think that a few people who go to Niagara Falls once in a lifetime should be given the esthetic pleasure of looking at the Horseshoe Falls and Whirlepool Rapids and 15,000,000 people be deprived of the use of the water power which can be developed. This potential power is not private property. It is not private property! The Niagara River is a boundary river between two countries. Riparian ownership of the Falls is in the Province of Ontario and state of New York and no rights can be had in that power except as are affirmatively given. To say that that power should be developed by the state under a state commission, is aside from the question. It is bringing up an entirely different question, the question of politics. Personally, I do not believe that the state of New York is now or will be for many years sufficiently well governed to manage such an industry as that, but I do believe that all the profit which can be derived from the Falls of Niagara beyond that which is necessary to interest capital to invest itself should be devoted to the public at large.

Finally, in regard to the local situation: I believe in large electric power producing corporations. They are more important where power must be produced by steam than when it can be produced by water power, because, the larger the units are, so far as the electrical and mechanical engineering art has gone, the cheaper the production, and the less waste. I am glad to see one, two, or three great electrical companies in Chicago. I would be glad to see the elevated railroads merge legally. I will be glad to see them merge with the street railroads and the electric producing companies with these. I think such a combination is desirable to this community. But when that has been accomplished, or, if that is accomplished, or if that is not accomplished, it is to be borne in mind that a street railroad or an elevated railroad or an electric light company is not on all fours with private business. The ownership to real estate is inherent in the individual who owns it. The right to use the public thoroughfare is a special privilege which is granted all the benefits, beyond such income as is necessary to interest capital, belongs to the granting power, which is the people.

February, 1912

In regard to the water power companies along the Illinois and Desplaines rivers, I wish to say emphatically, with a hope to be contradicted, that they have no legal rights.

I say, as a lawyer who has studied the question for many years, that the legislature, if it is left alone to its own untrammeled consideration, can enact constitutional laws which will take away from no man a right which he has, but which will assure to the public every horse power which can be developed from the water going through the drainage canal.

The legislatures and the courts are composed of individuals. These individuals make up their minds as other individuals do—partly by reason, partly by study, partly by instinct, partly by absorption. Impressions are deliberately put forth throughout this state, as I have said, warping the law. There is no official agency which can send out accurate conceptions of facts and of laws. We are not a monarchy. We have no king whose duty it is to preserve the rights of the state and no prime minister under him. The sovereign is the people. Even the legislature is merely an instrumentality, the governor an individual temporarily vested with authority. Public opinion, the will of the people, can only be created by the voluntary arguments of individuals, of societies, of political parties; and, for my part, the more this discussion is stirred up, the farther it goes, the more sure it must be that eventually the actual facts and the actual laws as applied to them must be established.

I count myself among the men who admire the extraordinary business ability, technical knowledge, and accomplishments of our electrical companies. There is only one reason why I have not invested any money in the shares of those companies, and that is the fear that when the time comes, as I anticipate, that there will be a hue and cry to put them out of business, as there was with the traction companies, as there was with the gas company, and I shall be arguing against such nonsense, that nobody will be able to impugn my motives.

I submit the necessity for thinking in national lines and in state lines and in city lines. We think too much in party lines; we think too much in the natural obstinacy which comes from conflicting views meeting opposition. As the President of the United States said, we are all in the same boat. The community will not be benefited by putting any corporation out of business, whatever aggravations there may have been, and no corporation will benefit by a blind insistence upon the belief that it alone is able to think for the community.

GOING VALUE

By Frank F. Fowle.

Presented November 22, 1911.

Engineering and economics were not supposed formerly to have any close or intimate relation, and prior to the last decade the realm of engineering was popularly understood to lie within the confines of applied natural science. But the decade just completed has witnessed a very important change in the early point of view, brought about almost entirely by the new problems which have sprung into existence with the rapid development of our public utilities. The engineer is now called upon to aid in the solution of the broad question of regulating our public service corporations, and there he finds himself in contact not only with the law, but that more interesting field of political science or economics, and almost of necessity he must absorb a good deal of both. A very able attorney once remarked that a successful engineer could never hope to evade the lawyers or the witness chair, and now perhaps we can go farther and say that sooner or later he will inevitably meet the political economist, in substance if not in form.

Going value is important in both its legal and its economic aspects, but particularly the latter, because it is one form of value and is thus property as much as though it had physical existence. We are probably accustomed to think of going value primarily in connection with appraisals of public utilities, but in order to maintain our ideas in proper balance, we ought to recognize that going value may exist in a business of any kind, irrespective of tangible or physical property. However, the present interest in the subject centers mainly around the particular case of public utilities.

It is essential at the outset to recognize that at the present moment there is no universally accepted view or theory of what constitutes or measures going value in a public utility. The treatment of the subject herein attempted is a review and discussion of the more prominent methods of determining going value which have come to notice from time to time, with particular reference to their application to public utilities.

THE DEFINITION OF VALUE.

The subject of value has been defined and discussed at great length by many authorities on economics, and therefore we may pass over it without extensive analysis.

Ely states that value in the generally accepted sense is exchange value, or objective value, in distinction from subjective value, which is the measure of importance attached to a commodity or thing by some one individual. He defines price as exchange value expressed in terms of money.

Hadley says that whereas price is a fact, value is what the

price reasonably ought to be, and further points out that while value sometimes may be used in the sense of utility, it ordinarily means the proper and legitimate price. He also states that value is essentially an ethical term, and therefore there may be as many theories of value as there are different views of business ethics. There are only two theories of great importance, however, the one being commonly known as the competitive or commercial theory and the other as the socialistic or cost theory. The distinction between these two views is of vital importance in our later consideration of going value.

Walker says that value is purchasing power or power in exchange, and he defines price as the purchasing power expressed in terms of some one article—such as money, for example. He draws a careful distinction between value and utility, the latter being always present where there is value, but utility alone does not invariably imply value in the economic sense. Among other elements which comprise value, he points out that cost and time are of major importance.

Summing up, we can say in the main that value is power in exchange and that it measures the reasonable price. Utility or usefulness is an ever present and most important element in value and without it there can be no value. But mere utility is of no value unless there is a desire or need which creates a demand. That is to say, something may be so common and plentiful that it has no value, although at the same time it may be very useful.

Under the theory of free competition, price is regulated by natural economic forces; it rises with increasing demand and falls with increasing supply, and vice versa. This is the competitive or commercial theory. On the other hand the socialistic theory fixes the price at no more than the cost plus a fair profit, and applies the principle universally to commerce and industry. The competitive theory fails to operate when competition is destroyed by the creation of a monopoly, and then the price may be fixed at the pleasure of the producer unless the law provides to the contrary. Except in the cases of public utilities and railroads we now rely on competition to maintain reasonable prices.

THE THEORY OF RATE REGULATION.

The theory of rate regulation as applied to public utilities has been extensively discussed and we can pass over it rather briefly. In the beginning there was only one recognized theory of rates, which was the older or competitive theory as propounded by accepted authorities on economics. Then came the rapid growth of public service enterprises from comparative insignificance to industries of great magnitude and public importance. Along with this development there began to evolve a public demand for the correction of certain abuses, which finally assumed definite shape in the modern theory of rate regulation. Thus there came to be two

fundamentally dissenting views on utility rates, which are well known as the value of service and the cost of service theories. The first springs from the competitive theory of prices, and is well stated by the early economic principle of charging all that the traffic will bear. In othre words, under that theory, the price charged for public service was based on the value of the service, measured by the most that it could stand. The second theory, whose application under modern public utility laws has now spread to about one-third of the states in the Union, springs from the principle that the public has an interest in a private corporation engaged in supplying public service. Such a corporation derives its right to exist and do business from the public and performs a service which the public may, when it so elects, perform for itself. It is therefore in the public interest that the rates should be no more than the cost plus a fair profit. We may observe here that this is an application of the socialistic theory of value, but not, however, because of any universal belief in that doctrine.

The cost of service theory, then, fixes the prices or rates at the lowest point consistent with the actual cost of the service plus a fair profit on the reasonable cost of the property used. Under the earlier theory the profits were not limited, however, except by natural economic forces. But when utility companies are forced to adopt the modern principle in rate making, they are entitled to some compensation for giving up their previous right to excessive or speculative profits. Such a return has been made, in most cases, in two forms. In the first place, the rates should never be less than sufficient to earn the fair profit, and various cases are on record where rates have actually been raised, in accordance with this principle; this should tend in the long run to make public utility securities safer and more stable, by establishing a sound value behind them. The fact that the modern principle of rate making aims at justice and equity in all cases, whether previous rates are too high or too low, is therefore a compensation in the respect that it greatly diminishes the hazards of the public utility business. In the next place, any utility company which gives good service and furthermore extends its service as fast as the public may reasonably demand, always presuming that it observes the law in letter and spirit, is fairly entitled to occupy the field in security against new-comers or competition. The last principle is recognized in the Wisconsin utility law, for instance, and various others, and is placed in effect by means of a device called a certificate of public convenience and necessity which is substantially a license to do business, and without which a new-comer cannot enter the field.

This brings us back to the question of competition versus monopoly. The modern or cost of service theory recognizes that a protected local monopoly in public service carries with it compensation to the utility companies for limiting their profits. It is also true theoretically that in a given local zone one company can serve

the public at a lower cost than two or more, with equally good service in both cases. This is always true as regards costs, but it does not follow necessarily in regard to rates unless there is very effective regulation; or, to put it in another way, the principle may not always apply in a practical sense. Without any regulation whatever, a local monopoly will be likely to result in higher rates than would obtain under competition. For economic reasons, however, it appears to be good public policy to promote local monopolies under efficient regulation, but it may be pointed out that this is far from endorsing monopolies in general, especially those of a national character.

The cost of service theory of rates raises at once several fundamental questions in every practical application. The first one is what constitutes the reasonable, legitimate investment for serving the public, or what is the cost of the property of every kind which is used and useful in the public service. The next question is what rate of interest and profits composes a fair return to the owners, and still another is what constitutes a reasonable cost of operation in serving the public. These matters are fundamental, and of course each one raises secondary questions of considerable importance. But the legitimate or necessary investment is the primary question with which we are here concerned.

TANGIBLE AND INTANGIBLE VALUES.

There is no single method which can be used invariably for determining the reasonable and fair cost of all the property of a public utility company. The most reliable and generally approved method is that of appraising the property to find the cost of reproducing it on the date of appraisal, or substantially on that date. This however is not always safe if the prices of materials, labor and equipment are abnormally high or low at the time, and such conditions must be taken into consideration. The book cost of the property is also important evidence if it shows the construction accounts and the actual outlay in creating or acquiring every part of the property; it does not always do this, however. The amount of outstanding capital stock and indebtedness is further evidence which should be carefully considered. These several methods of valuation apply, in general, in all cases, with the most weight probably given to the first or reproduction method.

It is perhaps proper to emphasize here that value and cost, as used in this discussion, are not always synonymous terms. Under the value of service theory they have the natural meanings attributed to them in economics, which of course are different; but in the cost of service theory, they become practically synonymous, since the whole theory rests on the proposition that nothing is of value unless it represents actual outlay or cost, and such value is measured by cost.

It is now well recognized that an established going business costs more than the mere physical plant and this has led

to a classification of values under the general head of tangible and intangible investments, as follows:

CLASSIFICATION OF VALUES.

- Total Value
  - Tangible
    - Organization
      - Promotion expense
      - Licenses and permits
      - Legal fees
    - Plant
      - Land and rights of way
      - Wells, intakes and suctions
      - Reservoirs, tanks and holders
      - Distribution system
      - Power plant machinery
      - Buildings and structures
      - Furniture and fixtures
      - Tools and teams
      - Paving
    - Construction Allowances
      - Engineering
      - Superintendence
      - Interest
      - Contingencies
    - Working Capital
  - Intangible
    - Franchises
    - Going Value
    - Good Will

The intangible values, comprised of franchises, going value, and good will, are very difficult if not impossible to separate. This is particularly true where a utility company is earning more than a reasonable return, and is not subject to regulation. There the margin of return above the reasonable amount might be capitalized and said to represent the entire intangible value, but it would hardly be possible to say how much of this value was represented by the franchise, or how much by going value, or again how much by good will. Before the days of regulation, it was regarded as legitimate to earn as much as the business would bear, even 20% or more. When a franchise gave the right to earn such profits for a term of years without interference, it undeniably possessed value, but the value did not exist until the business was established and going; nevertheless such a franchise would bring a considerable sum when offered for sale.

Under modern conditions the tendency is to regard a franchise as a contract between the utility company and the public, instead of a valuable gift which carries no particular responsibilities. Under fair regulation it offers the opportunity to make a comparatively safe investment, but it also carries certain duties and obligations toward the public. Furthermore it is often provided that the public may acquire the property by condemnation proceedings, for the purpose of public ownership and operation. In such an event it is hardly conceivable that the public ought to buy back a privilege which was granted free of cost; and besides there will be no

margin of value behind such a franchise due to earnings in excess of a fair return on the tangible cost or investment. However, the cost of service theory seems bound to recognize the actual legitimate cost or outlay for a franchise, made necessary by the usual course or procedure in obtaining it, but this can hardly be more than a nominal amount.

For the moment we shall pass over the subject of going value and consider good will. In the well known Consolidated Gas Case it was held that where a monopoly exists there can be no element of value in good will upon which the company is entitled to earn interest or profits. The obvious reason for this is the fact that the general public must take the service offered, or go without; it has no further choice in the matter. But where competition exists, it appears that good will is a factor in the prosperity of each company. Probably good will is to a large extent a matter of good service and considerate treatment; it is difficult to conceive of buying it, as one would buy some ordinary commodity. In a private business it might naturally represent a tangible cost, such as the entertainment of customers, for example, but this can hardly apply in the case of public service. Good will is a thing which every well-managed public utility desires for its own protection, and without which it can hardly feel that its earnings, present or future, are really secure; or, in other words, it is more of a necessity than a virtue.

THE NATURE OF GOING VALUE.

It seems to be almost impossible to formulate a definition of going value which will be universally acceptable. In general it has been taken to mean that element of value which is created by an active or going business, in addition to the tangible investment for property and working capital. It exists by reason of the fact that there is a live, productive business, and it would cease when the business ceased, even though the property could retain at the same time a value equal to its structural cost. The differences of opinion arise when we come to measure the amount of going value, or attempt to formulate a rule for determining it.

Some students of the problem have gone so far as to imply that going value is really inherent in the plant. This view of the matter is difficult to accept because it sets aside the question of earnings. In appraising a physical structure and assigning to it a value equal to its structural cost, we do not create that amount of value by the simple act of appraisal, but we merely state our best judgment of the actual cost. A value equal to the structural cost can only be established by a volume of net earnings which equals the usual or current rate of interest on the cost, in investments of similar risk and character. Actual value can only be established by net earnings, after meeting all operating charges and taxes and providing adequately for depreciation. This value may be more or less than the structural cost, depending upon the

volume of net earnings and the rate of interest which applies to the case in hand.

It is proper to distinguish between two general classes of business, at this point, and deal with them separately hereafter. The distinction is almost self evident; one class comprises private business of every kind, while the other embraces all forms of public utilities. It seems obviously proper to draw this distinction, for the reason that under modern conditions the economic forces at work in the two cases are fundamentally dissimilar, as already pointed out.

Generalizations on going value are so difficult that it seems necessary, in carrying on our analysis, to proceed by taking up the several methods of determining this element of value as they have been proposed from time to time.

THE METHODS OF DETERMINING GOING VALUE.

Numerous methods have been proposed for determining going value, some of them based on apparent merit and worked out with much ingenuity and ability, while others seemingly have been offered in the effort to uphold inflated values which could not otherwise be sustained. These proposals have been pretty well sifted by the public service commissions insofar as they apply, of course, to public utilities. Regardless of the kind of business to which they apply, the principal methods may be set down as follows:

1. Capitalizing the net earnings.
2. Finding the cost of reproducing the net earnings.
3. Capitalizing the early losses.
4. Capitalizing the cost of securing business.
5. Over-capitalization of consolidated companies.
6. Miscellaneous.

All of these methods but the first have been proposed mainly in reference to public utilities, where the problem of going value has raised so much discussion. Some of the difficulties surrounding the subject are probably due to the ingenious arguments put forward by those who have sought to maintain values or earnings which were threatened with reduction under the cost of service theory. Perhaps the sanest point of view can be maintained by discussing first the natural method of finding the going value in a private business, from the standpoint of the owner or investor. This is the first method enumerated above.

THE CAPITALIZED NET EARNINGS METHOD.

This method applies to all kinds of private business, and in one sense it applies to public utilities also, but under the cost of

service theory it excludes any going value which can be capitalized for the purpose of earning a return. In the case of a private business, going value is the value in excess of the tangible investment, created by capitalizing the whole net earnings, after meeting depreciation, at the rate of interest which is current for investments of like character, location, and risk. Taking a concrete example, suppose that the tangible investment is $100,000, and that the net earnings are $24,000 per annum; suppose further that the expected rate of return is 12%. The net earnings capitalized at this rate amount to $200,000, which gives a going value of $100,000 or 100% in excess of the tangible investment or property value.

This is the point of view in regard to the going value which a prospective investor in this business would presumably take. Of course, he would consider other questions besides the rate of return and the risk of impaired earnings; he would consider whether the investment is liquid, also the character and ability of the management and the men in control or associate investors, the title to the property, the past record of earnings, possible or active competition, patent litigation, the market for raw materials and labor, and kindred matters. The example considered above is obviously one of more than ordinary risk, which would be most likely to attract investors with experience which would fit them to assume the management or intelligently direct it.

This is the common-sense definition of going value in general business; it rests absolutely on earnings in excess of the expected or usual return on the tangible property. Where such a return does not exist there can be no going value in the sense here defined, and if the net earnings do not equal the expected rate of return, the going value will be negative; that is to say, the investment value will be less than the cost of the tangible property. Value is here established and measured entirely by net earnings, without regard to cost of the tangible property.

The cost of service theory measures value by actual cost or investment in the tangible property, as being the lowest value which is equitable. The rate of return which is regarded as reasonable depends upon local circumstances, but in the main it covers both the ordinary interest rate on secure investments and a margin of speculative profit; this is necessary to attract capital and stimulate development. The total return generally allowed is 7% to 8%. This makes it possible, with certain forms of financing, to show a margin of going value. Under the rule of conservative banking that a property should not be bonded beyond the point where the interest exceeds one-half of the net earnings, the stock can be made to show more than the rate of return allowed on the whole property. Consider, for example, a property which cost $100,000, and which is allowed to earn 8% or $8,000 per annum. Assume that the bonds bear 6% interest, but not more than $4,000

gross interest charges per annum; then it will appear that the stock has earnings as follows:

	Value.	Interest Rate.	Net Earnings.
Total.	$100,000	8%	$8,000
Bonds.	66,700	6%	4,000
Stock.	$ 33,300	12%	$4,000

The bond issue amounts to $66,700 and the stock issue to $33,300. The stock earns $4,000 per annum or 12%, and on an 8% basis each share of stock would be worth $150.00 on a par value of $100.00. This would apparently produce a total going value, based on earnings, of $16,700; but obviously this would not be a value which could be added to the cost of the tangible property for rate making purposes. It is also essential to recognize that the bonds represent a first lien on the property and the net earnings; the preferred stock would come next and the common stock last. Thus the stock represents to some extent a speculative margin where the financing is done in this way. It would be the first part of the investment to feel the effect of a falling off in net earnings and thus the market value of the stock might fluctuate, making it unwise to capitalize the going value which apparently exists.

It is also well to recognize that while such an element of going value is supported by the net earnings on the stock, it has no physical value behind it and would be wiped out if the property were taken under condemnation proceedings. Thus the trading in such shares at prices above par would always involve a risk which the purchaser must assume.

The clear intent of the cost of service theory of rates is to limit values to the fair cost of all the tangible property. Thus there can be no going value, under this theory, which is supported by net earnings in excess of a reasonable rate of return on the property. If this were not the case, the modern theory of regulation would fail to accomplish its purpose, and rates founded on the value of service theory, under former conditions, would continue to be impregnable.

THE REPRODUCTION OF NET EARNINGS METHOD.

This method of appraising going value was evolved some twelve years ago by civil engineers who were engaged in the valuation of water works. It has been very well described in a paper by Mr. John W. Alvord, on "Notes on Going Value and Methods for Its Computation," read before the American Water Works Association, at Milwaukee, 1909. The method is a general one, which may be applied to any utility provided the proper data are available. The cost of reproduction theory is very generally applied in determining the value of any physical property, but the present method of appraising going value extends the application of this

theory and aims to determine the cost of reproducing the net earnings of the business. The Railroad Commission of Wisconsin, in discussing the subject of going value in the Beloit case, quotes as follows from a report by Mr. Benezette Williams:*

> "All utilities that are distinctly public ones have a continuing existence. The acquired revenue of such utilities is also continuing and is the basis of an element of value which augments the physical value. This element is the 'going value,' or the potential business value, the amount of which must be determined by the net income which a plant in operation will have in excess of what a substitute plant of like character, the construction of which is begun at the time of valuation, can produce, the annual excess earnings being reduced to present worth."

This briefly defines the method, which seems rather simple in its conception, but is surrounded with certain difficulties in its application. Certain fundamental data are necessary, including the complete financial history of the business from commencement to date, the proportions of revenue derived from public and commercial service, the size and rate of growth of the community served and the general character of the demand.

The general supposition is that on the date of appraisal the existing plant and all of its business will be suddenly wiped out, and then, under the reproduction theory, work will be commenced at once to reproduce the physical property just as it was before, and the business which the old plant had will be acquired by the new one as fast as possible. The community served, however, is not presumed to change in any way from its present size and character, except through natural growth. Obviously some time will elapse before the revenues of the new plant will catch up with the probable revenues of the old one, and thus the act of reproducing the going business will entail some loss during the first few years. This method aims to determine the probable extent of that loss and then reduces the total amount, by discounting it at compound interest, to its present value and calls that the present worth of the going value.

The general procedure is to plot the total revenue, the commercial revenue, and the operating expenses from the inception of the business to date, or else far enough into the past to establish a safe guide for the future. The revenues from public service, such as fire hydrants or street lighting, are not taken into consideration, because it is assumed that these can be reproduced as soon as the new plant is ready for operation, thus entailing little or no loss. The commercial revenues and the operating expenses of the present plant are projected into the future, and by means of curves showing the established revenues and the expenses of the new plant, the

*7 W. R. C. R. 276.

date is found on which the revenues of the two plants will become equal.

An example of this is shown in Fig. 1, which is reproduced from Plate I of Mr. Alvord's paper. In addition to the curves shown, the population is often plotted, to aid in estimating the future revenues. The assumed date of valuation of this plant is 1905 and it is estimated that the two plants will have equal revenues after 1912, or a lapse of seven years. However, a period of one and one-half years is assumed as the construction period of the new plant, during which it will have no revenues. The point *A* shows where the commercial revenues of the new plant catch

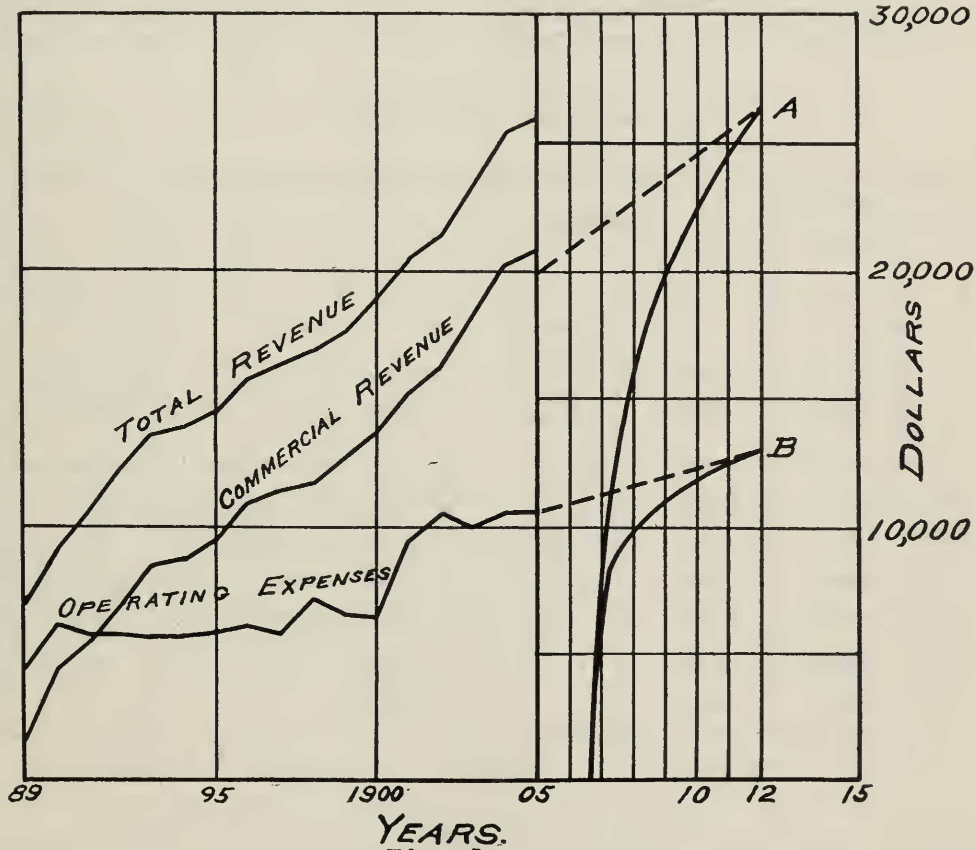

Fig 1

up with those of the old one, and the point *B* shows where the expenses of the two plants become equal.

This set of curves does not reveal the theoretical going value, but provides a means for calculating it. This value must be determined for each year until the revenue curves meet, then reduced to present worth and summed up, giving the total present going value. The calculations for the example shown in Fig. 1 are given below in Fig. 2.

The estimated present worth of the going value is $18,860 as shown by the footing of the last column in Fig. 2. This method

has been applied in numerous water works cases and also in some gas and electric cases, as showing the value of the going business over and above the physical values found by the cost of reproduction theory. A summary is given in Mr. Alvord's paper of twenty cases in which this method has been applied. It is interesting to note that the ratio of going value to physical value ranges from 9.6% to 47.0%, showing that there is no tangible relation between the two under this theory. Likewise there is no relation between going value and population, or the number of service connections, or the gross revenue. The period of recovery in these cases varied from 5½ to 11 years.

This method was used very recently in the report on water rates made to the mayor and the city council of Peoria, Ill., by

Computation of Going Value.

	Present Plant.	New Plant					
Year	Commercial Revenue	Commercial Revenue	Difference in Operating Expenses.	Total Credits	Annual Going Value	Factor	Present Worth of Going Value.
1907	$21800	$8500	$3500	$12000	$9800	.952	$9340
1908	22720	16000	1500	17500	5220	.907	4740
1909	23640	19500	800	20300	3340	.864	2870
1910	24560	22500	400	22900	1660	.823	1380
1911	25480	24800		24800	680	.784	530
1912	26400	26400		26400	0		0

Date of Valuation, 1905. FIG. 2 Total $18860

Messrs. Benezette and C. B. Williams. The value of the physical property of the Peoria Water Works Co. on Jan. 1, 1909, as measured by the estimated cost of reproduction, was $1,950,000, and the estimated going value was $865,096, or 44.3% of the physical value. The estimated period of recovery was 20 years. Generally speaking, the going value will increase with longer periods of recovery, a point which may be noted in connection with the rather large proportion of going value in this instance.

The same general method was considered also in the report on gas rates made to the Chicago council committee on Gas, Oil and Electric Light, by Mr. William J. Hagenah, but the value thus found was not accepted for rate making purposes. The present

investment value of the property, assumed for the purpose of calculation, was as follows:

Physical value	$42,000,000
Working capital	4,000,000
Going value	12,800,000
Investment value	$58,800,000

Assuming a recovery period of 10 years, the present worth of the going value was estimated to be $12,935,000, or nearly the value assumed in the first place. The investment value was taken into consideration only for the purpose of allowing proper credits for interest on the uninvested capital during the reconstruction period. This appears to be a refinement not taken into account in earlier applications of the theory, and it tends to reduce the final going value because it recognizes a possible source of extra income during recovery.

This method has been reviewed in several Wisconsin utility cases, first appearing in the *Cashton case. The last prominent case in which it was placed in evidence is the †Beloit case; there the going value claimed was as follows:

Water dept.	$ 63,996
Gas dept.	63,261
Electric dept.	46,473
Total	$173,730

The total reproduction cost of all physical property was $894,-204. It was assumed that the ratio of the rate of acquiring new business in the recovery period to the rate of acquiring the original or actual business would be double for the water department and triple for the gas and electric departments. In deciding the Beloit case the commission quoted as follows from the ‡Madison case.

> "The connected load or business is, of course, of value, but it appears to us that this value is covered by the cost of establishing the connections and acquiring the business, which costs, in one form or another, have found their way into the accounts of the company, and therefore constitute a part of the facts that are taken into consideration in appraising the plants. . . . . Possible future growth of the business can hardly be legitimately capitalized by utilities which are not entitled to more than reasonable returns on their investment; and this is also true of the rights to do business in a particular city, which rights have been granted free of cost."

This reproduction of net-earnings method has never, so far

*3 W. R. C. R. 85-96.
†7 W. R. C. R. 187.
‡4 W. R. C. R. 501, 578.

as the author is informed, received the sanction or endorsement of the Wisconsin commission. But the fact that it has been accepted in other cases entitles it to our serious consideration. Thus opinions differ as to whether it measures an element of value which is admissible in appraisals for transfer of ownership or for rate making.

It can be said in the first place that it measures no element of direct cost in building up a going business, and it bears no relation to the past profits, or the losses; and in fact there may be a going value, under this theory, in an unprofitable business. What the method really does determine seems to be this: It estimates the loss of income which would result if the present service contracts and connections were suddenly wiped out, along with the physical plant, and then reestablished as fast as possible after the completion of the duplicate plant, assuming that the public appreciation of and demand for the service proceeds as though there had been no change. But such a loss of income tells us neither the actual outlay or investment for building up the original business, or the reproduced business, and hence it seems to be not in keeping with the cost of service theory.

It is still a fair question, at least under the value of service theory, whether this method establishes a parcel of value which is quite independent of all the other elements of value which are ordinarily present. Granting now that a physical property has a value equal to its reproduction cost, what establishes that value? Surely not the mere act of appraisal or the statement of a theory of rates. It seems very evident that the value exists by virtue of the fact that the property as a going business will earn a fair rate of return on the cost. This is supported by the fact that appraisals are usually made under the assumption that the component parts of the plant are useful in their existing locations, in coordinate relations with each other, for an indefinite future period or until they wear out. Were this not so, the physical property could not be assigned a value equal to its structural cost, but instead it would have to be considered as a group of separate parts which would be thrown on the market and sold for what they would bring; this value, especially in the case of machinery and equipment, would be much less than the present value found by deducting depreciation from the reproduction cost.

Thus a new plant with no business has a value much less than its structural cost, except as regards the expectancy of future earnings. Undeniably a plant with connected consumers and a going business is worth more than one without business, but the one without business is worth less than its present physical value, or reproduction cost minus depreciation. It seems perfectly clear that the cost value is established by an amount of net earnings equal to a fair return. If then the net earnings give rise to a physical value equal to the cost, is it equitable to consider them a second

time as having a reproduction value, quite apart from the physical plant? That is to say, do the earnings have an intrinsic value over and above the value which they confer on the tangible property, where such property value does not exceed the cost? It would seem not, and yet the reproduction of net earnings theory seeks to establish this very proposition. Apparently this is like trying to eat your cake and have it, at the same time, because earnings which establish a value on the tangible property equal to the cost, and no more, cannot equitably be considered to establish simultantously some additional value. Of course if any intangible or going value is admitted at the start, it will appear in the final result, but that proves nothing.

If the net earnings are no more than a reasonable return on the reproduction cost of the tangible property, the application of this theory of going value will nevertheless produce an extra increment of value, which will then justify additional net earnings, and by a second application of the theory the value will be increased still more, and then in turn the net earnings,—and so on without limit. Considered from this point of view, the theory reduces itself to an absurdity.

One of the minor objections to the theory is contained in the fact that the present plant, if fully reproduced in the shortest possible time, will be somewhat too large during the first few years of recovery. This seems to be recognized in the presentation of the method in the report on Chicago gas rates previously mentioned, but so far as the author is informed this is the first instance. Another objection is the large element of uncertainty in speculating on the probable period of recovery, which materially affects the gross amount of the going value.

It is always a safe test of any theory of going value to inquire whether a prospective investor would recognize it and put his money into the value thus determined. If an engineer were asked by an investor to make a private report on some utility property, it is extremely improbable that he would apply this method of going value and submit it, along with the estimated tangible value, to his client. The measure of going value from the investor's viewpoint is earning value, present or future, and nothing else.

The author's conclusion in regard to this method, after much study of it, is that it measures no element of value which can be considered under the cost of service theory of rates. It might be admissible, however, under the value of service theory, where cost is not a primary consideration.

THE CAPITALIZED LOSSES METHOD.

It is well known that many public service companies failed to earn a reasonable return during their early existence, particularly those which commenced business many years ago. These companies are now reaching the period when their present and future

returns will be regulated in accordance with the cost of service theory. This raises a question of equity, because the pioneers who have failed, up to this time, to recoup their early losses from later profits, are now denied the opportunity to recoup themselves in the future. On the face of it, this would seem to be unjust, and consequently there has been a tendency to hold that a public utility is rightly entitled to a fair return on its tangible property, from the day it commenced operation down to the present moment. If in fact there were such early losses, they would now be capitalized, with interest, under this policy, and included in the value upon which reasonable returns ought now to be computed.

This in short is the plan which has been approved by the Wisconsin commission, under the name of going value. The selection of the name for this increment of value is not a particularly happy one, because it is not going value in the usual sense, but rather the capitalized value of deferred profits. In the *Madison case the commission said:

> "For public utilities which, under both the common law and the statute law, under normal conditions are only entitled to reasonable returns on the investment, justice as well as equity appears to demand that the amounts, if any, by which they, under ordinary conditions, have failed to earn such returns, should be considered in fixing values and rates for such plants."

In the ‡Beloit case the commission quoted the foregoing, and then added the following:

> "The early losses or deficits, or the amounts by which the earnings of the plant have failed to meet the ordinary operating expenses and taxes, and provide for depreciation and a reasonable return on the investment, will closely measure, in most cases, the cost of developing the business."

Now it is important to study the effect of this policy if pursued without the greatest care. Evidently the business which prospered least will now be entitled to the largest deferred profits or going value, and thus there may be some tendency to place a premium on mismanagement or bad business judgment. On this point the commission said in the †Madison case:

> "By this is not meant, however, that deficits from operation can be equitably taken into account in the appraisals or rates regardless of the conditions under which they were incurred. As already stated, when such deficits are due to abnormal conditions, or when due to bad management, defective judgment, extravagance, lack of ordinary care and foresight, unduly high capital charges, and other causes of this nature, it is manifestly clear that they should be accorded

*4 W. R. C. R. 501, 585.
‡7 W. R. C. R. 277.
†4 W. R. C. R. 501, 585, 586.

little or no consideration in either the valuation or the rates."

In other words, the local circumstances in each case must govern to a large extent. The next point which ought to receive consideration is whether, in now capitalizing deferred profits, the pioneers or actual losers will receive the equity which it is sought to establish. For example, they may have passed away, or they may have sold their securities, or the entire property may have been through reorganizations or receiverships, or it may have been merged with other properties and the old securities exchanged for those of the consolidated system. The Wisconsin commission said of this aspect of the matter in the *Madison case:

> "This is also likely to be the case for such deficits which were incurred under and borne by others than the present owners, and which have been wiped out in the various transfers of ownership. That these propositions are, as a rule, sound and equitable, appears to be so clear as to need no further argument."

Hence it is evident that this principle must be applied with great care to see that no injustice is done either way. Various examples of its use may be found in Wisconsin utility cases; the following illustration is taken from the †Beloit case, for the whole utility, including the water, gas and electric departments. This computation does not antedate 1906, when a consolidation of three independent utilities took place, to form the present system.

Computation of Earning Value.

Year.	Plant Value at first of year. V_1	Plant Additions during year. A.	Depreciation. 2.35 % D.	Interest and Profit. I.	Net Earnings. R.	Plant Value at end of year. V_2	Average Value for the year. Vo
1906	$474,251	$ 46,752	$11,094	$34,834	$49,464	$518,067	$497,627
1907	518,067	226,825	14,909	44,204	58,475	745,530	631,479
1908	745,530	74,543	18,450	54,796	66,549	826,769	782,801
*1909	826,769	33,806	9,861	29,528	39,517	860,447	843,672
1910	860,447	38,027	20,567	61,502	83,127	897,476	879,460

*First six months, to June 30th. FIG. 3.

The reproduction cost of the property on June 30, 1910, less the additions since the consolidation early in 1906, was $474,251.

*4 W. R. C. R. 501, 586.
†7 W. R. C. R. 280.

The methods of computing the value of the property at the end of each year is revealed in the following formula:

$$V_2 = V_1 + (D + I - R) \quad (1)$$

$$V_0 = \frac{V_1 + V_2}{2} \quad (2)$$

Thus the value at the end of the year equals the value on the first of the year, plus the additions during the year and plus the deficit from operation, if any, or minus the surplus. The total earning value on June 30, 1910, on a 7% basis, was $897,476. The total physical value, or reproduction cost, on the same date, was $894,204, and the present or depreciated value was $815,902. The commission held that under the local circumstances the cost of reproduction is not far away from the value upon which the company is entitled to earn a reasonable return; this included working capital of about $15,000 and the value of considerable water power. In this case there was no depreciation reserve fund, but there should have been, however, a total reserve of about $80,000 at least. In the computation of earning value it may be interesting to note the yearly surpluses and deficits, as shown below:

	Surplus.	Deficit.
1906	$2,936	......
1907	.....	$ 638
1908	.....	6,697
1909	128	......
1910	998	......
Total	$4,062	$7,335

A computation generally similar to that shown on Fig. 3 was employed in the report on Chicago gas rates, previously mentioned. Commencing with a property value of $39,000,000 in 1898, the final earning value in 1910 was shown to be $60,933,630. After adjusting this for certain later extensions and excluding certain property not employed in the gas utility, the earning value or amount upon which the report holds that reasonable returns ought to be computed is as follows, in round numbers:

Physical property, reproduction cost	$38,900,000
Working capital	3,200,000
Going value	9,400,000
Total earning or investment value	$51,600,000

Going value was present, however, in the original property value of $39,000,000 in 1898, which is a pertinent fact in connection with the going value of about $9,400,000 found to exist in 1910. The original value was made up as follows:

Physical property	$27,000,000

Working capital	2,000,000
Going value	10,000,000
Total	$39,000,000

The substantiation of the going value in 1898 will be taken up under the next method to be discussed. We can readily see that the method now under discussion might produce a very low earning or investment value, if the early losses were much more than offset by later profits. The question then arises, does the method work both ways? At first sight it would seem that it ought to, as a simple matter of justice. There can be no question that the requittal of early losses by later profits is entirely equitable, but in case these profits should be so large as to entirely wipe out the losses and furthermore reduce the earning value to a point below the reproduction cost of the tangible property, the matter of equity needs further consideration. Under the Constitution private property may not be taken for public use without adequate compensation, and the question here is whether previous returns in excess of a reasonable rate may be construed as lawful compensation for now fixing a value which is less than the reproduction cost of the property. It is difficult to see why such a construction would not amount to confiscation, and thus be unlawful, especially where the present owners or investors did not realize the extra profits. But even granting that it is not confiscation, as much care should be exercised to make sure that the present owners were the recipients of unreasonable profits in the past, as would be expended in the opposite case in making sure that the present owners sustained the early losses.

Early losses and profits may be wholly disregarded, from a new point of view, on the ground that former times constituted a speculative period and those who embarked in public utility enterprises expected no more than the usual fortunes of business, pocketing their losses along with the profits as part of the game. Of course the underlying motive in capitalizing deferred profits at the present time is the desire to do justice to the pioneers who invested their money in public utilities and have never had a reasonable return. This is simply the spirit of the square deal, but we should proceed with caution in order to make sure that justice and equity are truly served.

THE MERGED SECURITIES METHOD.

It is sometimes the case that two or more utilities are merged and capitalized for more than the cost of the tangible property. This may be a case of necessity owing to over-capitalization of the merged companies, or it may be deliberately planned by the promoters of the merger. A well-known instance of this kind arose in the *Consolidated Gas Case. In 1884 several gas companies in New York City were consolidated under the authority of the legis-

*Wilcox vs. Consolidated Gas Co., 212 U. S. 19.

lature and the rights and franchises of the several companies were admitted to possess a reasonable value of $7,781,000. This sum was included in the total on which securities were issued and sold, and afterward widely traded in, from time to time. The court held that the public approved of this transaction and could not afterward question it, but also held that this value had not increased with the progress of time and the enlargement of the business. The franchise value, as it was termed in 1884, we should now, in all probability, speak of as going value.

The Peoples Gas Light and Coke Co. was formed in 1897 under circumstances somewhat similar to those in the New York case. In the report on Chicago gas rates, to which several references have been made, it was estimated that there was a duplication of property in the 1897 merger to the reasonable extent of $10,000,000, and this was treated as the initial going value which the public cannot now question.

Under the principle that a public utility ought to be a local monopoly, it is the duty of the public not to force competition unless the company which occupies the field is failing in its public obligations; otherwise the company is entitled to protection. If, nevertheless, a competing and unnecessary franchise is granted, and a substantial property is built up thereunder, there is very likely to be a duplication of property and investment by the two companies. A subsequent merger will then result, in all probability, in a capitalization in excess of the cost of the tangible property which the consolidated company finds it necessary to retain and operate.

Sooner or later the time will arrive when the consolidated company comes under regulation. Then it becomes necessary to pass on the validity of any intangible capital which came into existence with the merger. As we have already seen, this question arose in two cases of great public importance. Two fundamentally-different cases can be distinguished in situations of this kind, which resolve themselves into one or the other class according to whether the public granted unnecessary competing franchises which later forced consolidation as a matter of self-preservation. Unquestionably such franchises were granted in the past, when public opinion was somewhat lax, but it is also fair to the public itself to point out that the granting of these franchises was done, in many cases, by corrupt public servants who were in politics for revenue, or in league with promoters who aimed to profit themselves by embarrassing the company or companies already in the field.

On the ground that the public is responsible, in the manner last described, for the duplicating of property in mergers of competing utilities, it seems just and equitable to allow a going value to the extent of the unavoidable duplication at the time of consolidation. This principle was recognized in the case of the Chi-

cago gas utilities. There is a question of broad public policy here, however, over the issue of whether such duplication value, or accepted intangible value, should now be capitalized for all time or gradually retired by an extra charge against the earnings until extinguished. The first plan produces the lowest equitable rates to which the present consumers are entitled, but burdens posterity with a charge for mistakes which were not theirs. The second plan produces, for the present, slightly higher rates than the first, but places the burden more nearly on those who were responsible. From the standpoint of the highest civic ideals the second plan commends itself as preferable.

Before passing to other considerations it may be noted that this form of so-called going value is not going value in the general sense, but duplication value arising from local consolidations which in turn were made necessary by enforced but needless competition.

THE COST OF DEVELOPMENT METHOD.

The development and up-building of any business commonly calls for expenditures beyond those which represent tangible property. Thus there is the matter of advertising and display, to educate the public. Special inducements to try the service are quite common, such as free house piping, or the installation of piping or wiring at the cost of labor and materials, or less than cost, with a long period in which to pay on the installment plan; also the sale at less than cost of various household utilities which consume water, gas or electric energy; and sometimes the use of free water, gas or electricity is offered for a limited period. There is also the matter of canvassing to obtain business, and to show consumers how to utilize the service economically and at the same time effectively.

Such costs are almost always present, and are ordinarily most burdensome during the early years or development period of the business. They may have been charged to capital or to operating expense, but in either case it seems necessary to consider them as one of the legitimate elements of cost, under the cost of service theory. The Wisconsin commission has expressed substantially this view of the matter, in connection with discussions of going value.

Probably it was common practice in nearly all cases to treat such costs as part of the operating expense. Thus the burden of business development fell heavily on the earnings of the early years and possibly diminished or wiped out the profits, for a time. Accepting this as a fact, it is obvious that the capitalization of deferred profits is a method of computing the so-called going value which fully covers the cost of developing the business up to the point of being a profitable going concern.

As regards latter day practices, it may be observed that the cost of getting business is divisible, at least for discussion, into two parts; one covers the expense for holding the present volume of business and the other covers the expense of securing an added

volume of business. It has been proposed that the first part should be charged to operating expense and the second part to construction or capital account. Such a division seems to be equitable enough, but there is some doubt as to whether it is altogether conservative. The creation of intangible values, or the addition to physical values of expenditures which do not represent physical property, ought to be restrained rather than encouraged. In other words, it cannot be regarded as conservative to attempt to build up values which do not represent tangible property. Therefore there is good reason for charging the cost of securing business to operating expense.

Selling cost, in a private business, is as much an element of the expense of doing business as the outlay for raw materials, or manufacturing cost, or overhead expense, and there is a continuing outgo of this character. If it is proper in a private business to treat selling cost as a part of the operating expense, is it not equally proper in a public utility? If the outlay in the latter case is made unusually large in order to attract, say, a new class of business, the expectation is that the later profits will more than cover the cost. It is also true that if the selling cost is charged to expense, there will be more effort to supervise it and hold it to a reasonable amount, than would be the case if it were charged to capital account.

Whichever way we conclude in the matter, selling cost, or the cost of building up and holding a going concern, is a legitimate outlay which we must recognize under the cost of service theory. In the case of an adjustment of rates at this time, the form or manner in which we recognize it is not so essential as the fact. Again we may observe that this is not going value in the broad sense, but simply an element of cost which demands recognition.

MISCELLANEOUS METHODS.

A variety of miscellaneous methods of arriving at the going value have been proposed from time to time. These methods are only of passing interest, but will be described briefly.

A going value was claimed, in one instance, equal to one-half of one year's gross receipts. The theory behind this claim was never made clear, but on the face of it there would seem to be no relationship between the gross earnings and any of the factors which have heretofore been classed, under the cost of service theory, as going value.

Another method proposes to fix the going value arbitrarily at one-third of the value of the physical property. This leaves out of consideration the net earnings and the cost of developing the business. It might be supported, apparently, by the rough average of going value as found by the reproduction of earnings method, which was previously treated at length. This ratio of 33⅓% for going value in terms of physicial value was varied in another

proposal to 27%, as being about what investors would pay for the intangible assets.

It has also been proposed to assign a going value on the basis of so much per connected customer, this amount being in one case $30.00. The arguments behind this proposal, aside from the cost of securing the customers, were not very definite and covered the good will which exists in the sense of an established, developed business.

Another proposal was made to fix the going value at an amount anywhere from one-half up to the full sum of one year's gross receipts, on the ground that utility managers would be willing, ordinarily, to spend as much as that to secure the business. Of course this proposal tends back toward the cost of development idea.

These several methods can perhaps be classified in a general way by saying that they would be admissible under the value of service theory of rates, but not under the cost of service theory except insofar as they reveal, if at all, any legitimate elements of cost in building the properties and developing the business.

CONCLUSIONS.

1. Under the cost of service theory we seem bound to recognize every element of actual cost, for both tangible and intangible property, which is legitimate, reasonable, and necessary.

2. Going value, under the cost of service theory, cannot be supported by capitalized net earnings in excess of a fair return on the cost value of the property.

3. Rigid rules for measuring the legitimate going value, if any, under the cost of service theory, cannot safely be laid down, because the local circumstances in each case are different and each issue should be treated on its merits.

4. The general test for value of any kind, under the cost of service theory, is always the cost, but this may be tempered by the great desirability of distributing justice and equity to both the public and the utility companies, in equal measure.

This paper is not conceived in any thought or attempt to say the last word on this very important subject, and free and open discussion of it is greatly to be desired. Some may approach the question as partisans on one side or another, but disinterested engineers ought to finally agree, if possible, on the major points now at issue.

APPENDIX.

REFERENCES ON GOING VALUE.

"Notes on Going Value and Methods For Its Computation," paper by John W. Alvord, read before American Water Works Association, 1909.

"Report to the Mayor and City Council on Water Rates for the Plant Belonging to the Peoria Water Works Co., Peoria, Ill.," by Messrs. Benezette and C. B. Williams, 1910.

"Investigation of the Peoples Gas Light & Coke Co. for the Chicago

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Racine case, 6 W. R. C. R. 276-286.
Beloit case, 7 W. R. C. R. 276-282.

Editorials:

Electrical World, Jan. 26, 1911, p. 221.
Electrical World, April 6, 1911, p. 821.
Elec. Review and West. Elec., July 1, 1911, p. 2.
Electric Railway Journal, Nov. 4, 1911, p. 976.

Discussion.

Mr. Fowle: Before commencing the discussion of the paper, I wish to point out that this is a complex subject on which there are many honest differences of opinion. I have tried to present it as I see it, but of course no individual is infallible, and I am as likely to be wrong as any one else. I simply ask that you keep these things in mind in discussing my presentation.

J. G. Wray, M. W. S. E. (Chairman): I am much interested in the subject which Mr. Fowle has presented to us this evening—Going Value. It is of special, vital interest to all public utilities, as we are now, in a number of states, under the jurisdiction of State commissions having power to regulate rates and regulate the issuance of securities. The value of a property, of course, depends on a good many factors and there are a good many different ways of measuring the values. There was a time, of course, when property was appraised on the market value of its stocks and bonds and other securities; and until the state claimed and exercised its right to regulate the rate of return, to regulate the earning power of such a utility, the former method was acceptable. It depended upon the rate of return and therefore is fallacious when you concede the power to regulate that rate of return. It was later argued that the physical value of the property was the proper basis for rates, but that has been found to be a mistake, because there are other values in a property than the physical values. A plant like that of the telephone company is worth much more as a going concern than the physical plant. The plant built and ready for service is worth a good deal less than the same plant in service and yielding a return, and, furthermore, it costs a good deal to get such a plant going. There are a number of methods of determining that

going value, and I am sure the discussion will throw a good many side lights on a mooted question.

The Warehouse and Railroad Commission has recognized a going value, but to my notion it is a wrong basis. The courts in some cases have followed the lead of the Wisconsin Railroad Commission. In other cases they have recognized the going value as being related to the value of the plant rather than to the earnings of the plant. Going value seems to be a complex value, and to involve an intangible value, or rather, what we might call one of the factors of overhead expense in a specific plant; that is, the cost of getting and connecting up the customers. It also involves possible losses,—deferred profits, as Mr. Fowle has styled them,—and it involves an element of value which should be the result of good management. We can conceive of one company that has planned and constructed its plant economically; and has built up its business economically. We can conceive of another organization, perhaps under identical conditions, that would build a plant uneconomically, that would be slow, and get its business in an expensive way. Surely the first company is entitled to a greater element of value in its property than the second, but the great question is how to secure these factors.

Benezette Williams, M. W. S. E.: To adequately discuss the paper that we have heard tonight would require a treatise, and I am not prepared to give a treatise offhand. However, a great deal of confusion may be eliminated by confining ourselves to a few fundamental principles based upon the fundamental facts which underlie questions of valuation.

The matter of capitalizing net earnings has no standing in the valuation of public utilities, either before the courts, or before public service commissions, and it can never be properly used as a measure of going value. There are but two fundamental methods of determining the value of a public utility.

One is the cost method, which Mr. Fowle brought out very clearly; namely, the cost of construction plus the cost of developing the business. Under this method, economically speaking, there is no such thing as going value, the substitute therefor being development costs. It is the identification of this with going value, that brings confusion, and causes trouble in valuations. Under this method, what is properly termed the plant investment is determined by the cost of the plant, plus the cost of developing the business.

This method has probably been presented by the owners of public utilities, in one form or another, to every court of the land that has heard a public utility valuation case.

The other of the two methods consists in ascertaining the economic value of the plant, or the value of the investment, as distinguished from costs.

To get the historic setting of these two ways of determining the investment for a public utility, it is necessary in this country to go back fifteen or twenty years to trace court decisions, and for twenty to thirty years, in some cases forty, for the beginning of the conditions that have led up to the appraisal of public utilities.

We all know that building water works in the United States under limited municipal franchises, began prior to 1880, and in some cases prior to 1875, and continued with greater or less activity until 1893. Soon after the latter date the earlier franchises began to expire, and near the same time municipalties, or at least many of them, became impressed with the idea of public ownership of water works. The maturing of franchises, combined with the sentiment for municipal ownership, ushered in a period during which appraisements of public utilities, and particularly of water works plants, became more or less active. In determining the value in many of these cases, the courts were appealed to, and judges of the higher courts began rendering decisions which laid down the doctrines and principles which should be followed in such cases. Among the earliest of these decisions,—indeed, the earliest important one—was probably that of the National Water Works vs. Kansas City. Fortunately for this company, and fortunately for the cause of sound economic reasoning, and the cause of justice in cases which were to follow, the Kansas City case reached Judge Brewer on appeal to the United States Circuit Court. The decision rendered by him, I believe in 1894, has become the groundwork for every legally, and economically sound appraisement, and court decision, relative to public utility values, that has been made or rendered in this country during the eighteen years last past.

In this case the company contended for the capitalizing of earnings to determine the value of the plant. As a parallel contention they argued for a value in excess of the cost of reproducing the plant. The city, as all cities do, contended for the cost of reproduction less depreciation, as the measure of value, or what has been well termed the junk theory of values. At the time this appraisal took place the prices of labor and materials had declined to near the lowest point that they have reached in fifty years. Under such conditions, the reproduction value of the physical plant was necessarily low.

Before the case reached the Circuit Court of Appeals, the District Court appointed a commission of engineers to estimate the physical value of the plant. This commission seems to have reached a value considerably above the net cost of reproduction less depreciation, by allowing liberally for interest during construction. The District Judge fixed a price considerably higher than this commission. When it reached Judge Brewer, a man of broad comprehension and keen intellect, the price fixed by the lower court

was raised from about $2,700,000 to $3,000,000, on a thorough analysis of the contentions advanced in the case.

He held: That the junk theory—he did not use that term, but I use it because it is short and expressive—of appraisement was not admissible; that the cost of reproduction did not cover the ground; nor was the capitalization of net earnings allowable; but he said the plant is worth more than the cost of reproduction because it has a business. Not because it had paid dividends in the past; not because it had cost something to build up the business of the company, but it was the business itself that gave it an additional value.

This brought the following proposition squarely before those who in the future might be called upon to make appraisements: If a public utility is worth more than the cost of reproduction because it has a business, such increased value can only arise from some part of the revenue it is going to produce in the future; otherwise no value could be realized by the purchaser in excess of reproduction value. This raised the further questions: How is this additional value to be measured? How is it to be described?

If you will but concentrate your minds upon this conception, throwing aside all subsidiary questions that lead to confusion, you will be compelled to admit that it is the revenue which the plant in operation will produce that would not be produced if that plant had had no existence, and the alternative was to build and put into operation a new plant identical with the old one. In other words, it is the revenue which the operating plant will produce, that a new plant starting in the same, though unoccupied, field would not produce. Or, stated in another way, it is the service measured in revenue, which the plant in question will give, that can be had only by the continued operation of the plant itself. Thus the Kansas City decision brought clearly before appraisers, and courts, the necessity of determining values by values, not by costs, but, so to speak, by costs reduced to their real worth.

The formulation of this conception of going value was made by the speaker when acting as one of the board of appraisers for the Dubuque Water Works in 1899, and a method of computing it, with the aid of diagrams based on operating data, was first developed by him at that time.

By the way, while I am on this subject, it may be well to remark that the author seems to think that this value of which we speak, would not be enticing, or would offer no inducement to an investor.

Let us hypothecate two cities of the same size, substantially, and the same in every respect, except that one has a public utility—we will say a water works—while the other has none; this public utility in the one city has been developed to where its business is carrying it under a scale of rates giving an ordinary, allowable revenue, with reasonable profits; and it is presented to a financier

to decide which one of those cities he will choose as a field for water works investment. He sends his engineer to help him to decide, by estimating the cost of a water works in the city that has no plant, and to determine what it will cost to build up the business of the new plant to the level of the old plant in the other city.

Having determined the rapidity with which business can be obtained in the city without a plant, by the experience of the operating plant in the other city, and the cost of operating the new plant to the level of the old, the engineer will next compare results with the operating record of the old plant, and obtain a balance between difference of revenue and difference of operating expenses. He will next obtain a balance between the structural value of a new plant, and the structural value of the old one.

The first balance gives him what the old plant will yield in the way of revenue that the new one will not. This is the going value of the old plant, because it is the revenue it will give that no other plant can be made to produce. With this going value, and the physical value of the proposed new plant, and of the old one, the engineer can present a general balance to the investor which will enable him to decide between the purchase of the old plant at a given price, in the one city, or the construction of a new plant in the other city.

Is not this the method the engineer would pursue under such conditions? Is there anything fantastic or unusual in such a course? Is it beyond the powers and reach of any competent constructive and operating engineer? Assuredly this is the method he would adopt, and if he was competent, he might estimate the going value as closely as he would estimate the value of the physical plant itself; provided he had the necessary data; that is, the operating record of the old plant from the beginning, showing its growth, and its magnitude, compared to the city it serves, the population of the city, and other elements necessary to an understanding of the problem.

After these things had been done and the differences reported, the investor probably would say, "I believe that this difference exists. It is clear I can afford to pay more money for the old plant, the one that has been in operation for years, than to build a new plant in a city that has had no plant, but I would want some margin of value as an inducement to purchase the old one. I would want a greater profit and would not take it for your total estimate."

But there is a point much in excess of the cost of the new plant, at which the investor would accept the old, rather than to take the risk of building and developing the business of the new from the beginning. This excess is the real commercial going value of the old plant, properly speaking. If we confine ourselves to the proper use of terms, we must all agree that this element is the only one arising in public utility appraisements, that is entitled to be dignified by the term going value.

Development expenses of public utilities, often spoken of as

going value, are not necessarily value at all. They are the costs of developing the business of the plant, and in the determination of the investment on the cost basis, they become the legitimate substitute for going value. They may, or may not, have produced a value equal to the outlay. No higher court, so far as known, has ever admitted that development expenses can properly be made a measure of economic value, though they hold that it is proper to consider them in evidence.

Public utility commissions have sometimes classed development expenses as going value, that should be included in an appraisement as such. This position, however, was not long maintained after a few statements of deficits had been submitted by owners of utilities. Deficits can never long be patiently considered as an element in valuation. By fallacious reasoning they may theoretically be held to represent value for a time, but the time is usually short.

This statement is well exemplified in the reports of the Wisconsin Railroad Commission with reference to the valuation of public utilities. This commission seemed to start along the lines marked out by court decisions, on a correct theory, and their first decisions expounded the true doctrines of valuation. But for some reason, in less than a year, they had reversed themselves and were expounding the cost theory with great emphasis, and great clearness, and on the basis of that theory, with correctness. But today they are at a point where they seem to hold to neither. In practice they neither admit development costs, nor that going value which grows out of the business itself on any consistent basis, or in any adequate manner.

Courts have consistently held to the position taken by Judge Brewer in the Kansas City case. It is probable that no court of last resort, when the principle has been present, has varied from this decision since it was made.

I have no controversy with the cost proposition, provided the plant has been built under government regulation, and the costs actually entered up and credited to the plant when it comes to be appraised. But it does not apply, and cannot be made to apply intelligently or equitably, to the valuation of pioneer plants, built under limited franchises, that have started with no business, and after a long dry season, have grown to a point where possibly they are carrying themselves.

There is this further thought which may be helpful, namely, that a public utility never reaches completeness in any given field until it has saturated the territory that it covers, that is, not until it has practically acquired all business that is to be had in that territory, on a scale of rates that will bring proper remuneration. From the time that it was installed up to the time of remuneration it has generally gone through a season of deficits. There is little variation from this experience. Compensation for such losses can

only come out of the plant itself, either by capitalizing the deficits, or supplying this deficiency by the inclusion of the going value element.

I want to say something about the proper use of terms. If we could always distinguish things that differ, and use terms with the same meaning attached under all conditions, much confusion would be avoided. A common example of the misuse of terms is found in classifying good will, as a public utility value element. There is no such thing as good will connected with a public utility. We resort to the public utility for a service because that is the only way the service can be had. I would go from here to Milwaukee over the only railroad, if there were only one in operation, rather than to walk. but I would not do it because of good will. Good will implies free will, the possibility of a choice. If a consumer, purchaser, or patron goes to a certain place for a thing or service he wants, while there was the possibility of his going somewhere else for the same thing, he is exercising good will, because it is an act of free will. If he chooses to go there in preference to some other place, because he likes the goods, or likes the dealer, or from any other cause, that is good will. But no such choice applies to a public utility, hence a public utility has no value element that can be classed as good will, and even if it had, there is no way of measuring the magnitude which it should assume in an appraisement.

Another confusion of terms is found in the use of the words tangible, and intangible, as applied to values. It is common to speak of the estimated cost of physical property reproduced, as being a tangible value. Now, the property may be tangible, but the value you put on it, intangible. The value may be something today and another thing tomorrow. I have valued plants for which the cast iron pipes cost $69.00 and $70.00 per ton when built. At the time of valuation such pipes could be bought for $25,00 per ton. There would seem to be little tangibility to a value based on the original cost in such cases. The pipes referred to are, however, still in use and decidedly tangible.

As applied to this element of going value of which I speak, that is, the real going value, the thing that is actually desired and is sought after, the something which cannot be divorced from the plant, and can and will be realized by the one who operates it in the future, the word intangible is most unfortunate. Instead of being notably intangible, it is relatively the most tangible value element about the plant. It may be said that the rates are too high, and hence this element is not tangible. True, the rates within certain limits may have to be adjusted, but the service which the plant is rendering its patrons is sure to continue, and in a manner to give substantial remuneration. The price of materials may slump, the structural parts may and will gradually disappear for one

reason or another, and be replaced, but the earnings of the plant go on without end as long as the community lasts.

The Railroad Commission of Wisconsin confused these terms. They said that this going value, the real going value, was an intangible value, and that though a purchaser might be willing to pay more for the utility because of it, it is not property used and useful for the convenience of the public. They rightly considered that the physical plant is property used and useful for the convenience of the public, but failed to discriminate between the property itself, and the elements which affect its value. The element of going value which affects the value of real property does not differ in this respect from any other element of value. Market price changes for instance.

If the price of cast iron pipe goes up, the value of a water works plant will rise; if it goes down, the value will fall. But the increment of value created by such changes is not property used and useful for the convenience of the public. Not nearly as much so as the increment created by the business element, for this reason: That it has business, means that the plant is rendering service, and whether the business has attained the point of carrying the plant or not, it means that it is nearer the point that it will do so; that the time is not as remote when rates may be reduced, or when extensions can be made without an increase of rates. Hence, though business value may not be property used and useful for the convenience of the public, it is an attribute of property that is so used. On the other hand, market fluctuations of materials, or of land, are not even attributes which are used and useful for the convenience of the public.

Hence, reverting to the correct use of terms, it is necessary to discriminate between property itself, and those attributes, or economic forces, which change the value of property. Property is one thing—its value quite another. Some of the value elements tend to render the property more useful, while others do not, but none of them has any existence except as an attribute of the property.

I wish to say one word about this term, going value. I think that it is a very involved term—a very unhappy one. It does not properly express the thought. I believe that the more correct term would be "business value," or "revenue value," whichever may be preferred; or the term, "service value," may be even better. Correctly speaking, the real going value of a plant is its total value, the algebraic sum of all positive and negative value elements. This is its value as a "going concern," without reference to the character or origin of the various economic elements that appreciate or depreciate it.

There are many other things in connection with this subject that might be said, but the discussion has already strung out too long. If we could only keep these fundamentals, these distinctions in our minds, and discriminate in the use of terms, a great deal of

fallacious reasoning and confusion of thought would be done away with.

Mr. Wray: I would like to suggest that perhaps there is an element of good will in a public utility. The wayfarer has the opportunity of taking the surface line or the elevated or perhaps the steam road. The customer has the opportunity of taking electric light or gas or perhaps using kerosene lamps or coal stoves, or he has a chance to telegraph, telephone or send a letter. I am not at all sure but what there is an element of good will in the public utilities.

I would like to suggest further that if I understand Mr. Williams' explanation of going value, particularly the service value, there surely must be a large element of going value in the telephone as compared with the water works. As a telephone subscriber, I am much interested in the large development of the telephone business, but in the water company my interest is not so great, because if I am well served I am satisfied.

J. W. Alvord, M. W. S. E.: It is refreshing to hear a paper written by an engineer who evidently has read along the line of economics, and who has some fundamental principles well in mind; who does not, for instance, make the common mistake of confusing value with cost. The paper read very well to me until I came to the part which led up to this paragraph:

> "If, then, the net earnings give rise to a physical value equal to the cost, is it equitable to consider them a second time as having a reproduction value?"

That I confess I had to read over twice. It did not ring true to me. As I understand the author's argument, it is this: that the very existence of the revenues necessarily make the physical property of value, which of course, cannot be denied; but, therefore, we must not again consider the revenues themselves as anything which it costs money to create. To illustrate what seems to me to be fallacious in that conclusion, I might suggest that you can have a plant with with a steam engine in it. The steam engine is absolutely vital to the operation of the plant, therefore it lends value to all the rest of the plant which is useless without its presence. Why, therefore, value the steam engine itself? If I catch the intent and meaning of the argument, the author has used, that would seem to me to be a parallel illustration which would disclose its departure from a correct conclusion. The writer does not, evidently, think that the created income would really cost anything to recreate. I think perhaps that his conclusion could best be shown to be erroneous by citing a concrete case.

Some years ago I was employed by a city of 30,000 people, to advise them about building a duplicate or rival water works plant. They had employed an engineer who had estimated that it would cost them a certain sum of money to build the physical part of a plant that would be capable of doing practically the same service

as the existing plant owned by the private water company, but his estimates had stopped with the physical property. The first thing it devolved on me to do, was to say to the board of trustees, "Gentlemen, it is to be regretted that you haven't all of the cost before you in considering the advisability of this project." They pricked up their ears and said, "Why, what is left out?" and my answer was, "When you get this physical plant which your engineer has estimated for you, built, you must still run it at a loss while you acquire business and revenue, and that is certain to cost you money which has not yet been estimated, and not only that, but while you are building the physical property, the existing plant is earning revenue all the while." These gentlemen were not at all dull, and they looked at each other and they looked out of the window, and they finally adjourned to talk it over, and the next day they met again, talked it over again. They finally concluded that it was pretty nearly so, and as a matter of fact, it was an incontrovertible proposition.

Now, that is what every city is really up against when they take up the question of building a duplicate or rival utility plant, for here is a plant they can buy which is already earning, and it is inevitable that if they decide to build they must wait until they complete before they can even begin to earn. Of course, if a city attempts to create a revenue under competitive conditions, they will certainly expend more for going value than they would in a proposition without a rival, although that feature does not concern us here as it does not enter into our problem.

There are a number of other points I would like to discuss in Mr. Fowle's paper, but I will pass them because they are minor in their nature. The main thought which the writer of this paper has in mind is that the Wisconsin Utility Commission's idea of taking the past cost and the past deficits and adding them to the reproduction cost of the physical property, is the best way of getting at going value or one of the good ways of getting at going value, and he concludes that the reproduction method of estimating going value is not so good a way of arriving at it. I strongly dissent from that position. I feel that the Wisconsin Utilities Commission is a fine body of high minded and conscientious men who are endeavoring to do just as near right as they know how, both in the way of fairness and justice, but I think that they lose sight of correct logic and true fundamental principles when they take the attitude in question, and notably they put themselves at variance with all the trend of thought of the courts, who are also trying to thoughtfully and consistently solve this problem. The courts have been studying this question for a long time. Long before the Wisconsin Utilities Commission came into existence, they had defined going value and enunciated several important principles which have stood the test of time and argument.

Now I do not know that the Wisconsin Commission call their

method of past cost and deficit, going value, but the author of this paper assumes that they do, and I think that in so doing, he perhaps does them an injustice, for it is as certain as anything can be that the deficits incurred in a failure to earn a fair return in the past is not what Judge Brewer had in mind in the Kansas City case when he defined going value as follows:

> "The fact that it is a system in operation not only with capacity to supply the city, but actually supplying many buildings in the city not only with the capacity to earn, but actually earning, makes it true that the fair and equitable value is something in excess of the cost of reproduction. * * * It should pay, therefore, not merely the value of a system which might be made to earn, but that of a system which does earn."
>
> (Nat. Water Works Co. vs. Kansas City, 62 Fed. 865.)

This something that Judge Brewer had in mind was therefore something belonging to the reproduction method, something to be reproduced besides the mere physical property, and the comparative method which Mr. Fowle has clearly described is an honest effort to logically follow out the court's line of thought and reproduce this element of value. Now what the Wisconsin Commission adds to the physical property from deficits in the past, however just a result it may seem to produce, or however fair it may look, is certainly not an attempt to estimate going value as the courts have had it in mind, nor is it following the line of thought of the courts as to carefully separating past cost methods from reproduction methods. I wish to further, show that the courts have not fallen into this confusion but have kept clear certain fundamental principles which are vital to clear thinking.

These principles are briefly, that there are several ways—"yardsticks" we might say—by which we can arrive at values through cost. One of the first of these methods they say is to determine what it will cost to reproduce a property; another way is to determine what it has cost in the past (if that could be disclosed) to build up a property, including the revenue; a third method is the market value of the stocks and bonds, if it can be shown that an adequate, proper and a reasonably active market for such stocks and bonds exists, and finally, another method they have mentioned is the commercial or comparative method, the value that an ordinary business man would place upon such a property, in view of the population, the revenue, the future growth, and all those kinds of considerations that are general only. They say these things are all lines of evidence; we should have them all before us, if it is possible, or at least some of them, and they mentioned reproduction as one of the most advantageous to have before us, but they say these cost methods are not values, they are merely elements which will help us to arrive at values. This they have made very clear in many decisions, commencing with the instructions of the

Supreme Court of Maine in the Waterville case, and from which they have not departed so far as I can learn. Now, some commissions and many appraisers have mixed up these various yardsticks so that you cannot tell what special one they are using. For instance, in reproduction, they will reproduce up to the point where they have the physical property all complete. They then stop reproduction and go back into the past cost methods to find out what some deficits in the past were, and they add that to the reproduction of the physical property. That, it seems to me, is mixing past cost and reproduction into something which is neither one thing nor the other. To my notion, if we are going to reproduce a plant as of today, let us reproduce it clear through to the bitter end, whereever that end may be—plant, property, business and everything. Let us reproduce it completely; then we have that yardstick method finished. Let us lay that aside. Then let us go into the past cost method and if we can find from the books what the past cost has been to build up the plant, and further, if we find there have been deficits, why, let us add those if you please, as part of the past cost method. Let us complete that, and lay it aside. Then, if there are any other methods, the stock and bond method, which would throw light on the subject, let us have it also in the record of testimony before us, and when we have all these cost methods before us, let us sit down and reason as to which one of them, or which group of them comes nearest to throwing light upon the subject of the real value of the plant. Then is the time when the judicial function, the reasoning mind, can operate in fundamental deduction, eliminating detailed figures for the time being and taking the general evidence before us to arrive at the true value. This mixing past cost with reproduction, to my notion, simply confuses us completely; it throws dust in the air, and it gives us a feeling that there are no underlying principles to follow. Now, the courts feel that there are important underlying principles all the way through the matter, and they should be consistently followed. Now the comparative method of estimating going value which Mr. Fowle has illustrated very clearly is merely an attempt to pursue logically the same kind of reproduction that we have been using in the physical property, through to the end in a reproduction of the business or revenue, in a consistent way. That is why it has become a favorite with appraisers so far, because it is consistent with the rest of the reproduction method which the courts would have us present to them.

We have to do a good deal of clear thinking on this subject, and to do clear thinking we have to have definitions, and my definition for what is commonly called going value, is that it is *the value of a created income,* and if you are going to use the reproduction theory of determining *cost,* then as used there, it should be called the cost of reproducing the income. The comparative method which has been described is not any one man's method, although

Mr. Williams is entitled to the credit of first suggesting the general outline. It has been developed by a good many different appraisers in perhaps fifty different appraisal boards, where trained men with opposite points of view have met each other and have had to reason with each other or testify before courts and under cross-examination. It is that kind of test which brings out the logic that is fundamental and truth that permanently endures, and it seems to me we should not lightly throw aside the results of such experience which has been tested and tried so fully by such crucial methods, for it has a value that should be undoubted, and because the student of this subject does not get clearly all the logic at the first attempt, is not evidence that the method is not well founded. One should be somewhat cautious in taking up such a subject, to get fundamental principles clear, for they are absolutely necessary in understanding details.

Mr. Fowle does not seem to have seen a further paper on "going value of water works" written by Mr. Leonard Metcalf and myself, and published in the proceedings of the American Society of Civil Engineers, Vol. LXXIII, page 326 (1911). This paper works out the matter in much detail, as is found necessary in plants of magnitude, whose construction period extends over a number of years, and whose different parts go into service at different times. It illustrates some of the refinements of the method better than is done by any example of the comparative method in the paper quoted, but it is always, of course, desirable in this problem to keep the proposition as simple as possible if it can be done without great deviation from the results warranted by fact.

W. J. Norton (Commonwealth Edison Co.): I would like to call attention to a certain rate case, in which practically all of the methods were used. This is the Des Moines gas case, in which two engineers used the method of reproducing the income, and another engineer used a method based upon finding the cost of acquiring the new customers as against the ordinary business which the company would have obtained, due to its natural growth. Then again another public utility expert presented in the case the Wisconsin going value method. I call attention to it because it seems to me that this case has been very ably presented by the company. Personally, I have taken a great deal of interest in it, and I think it shows all that can be done in advancing the theories of going value. I understand that the final arguments are taking place now, and I look forward to the decision in that case as solving, in a great measure, the relative value on the different presentations of going value.*

M. G. Lloyd: I am not an expert on making appraisals or

*Since this discussion was presented the Master has thrown out all testimony relating to the Wisconsin, or early loss theory, on the ground that such testimony is incompetent in a case based upon the confiscation theory.

on going values. I have not made the study of the subject that the previous speakers have. I have, however, given some little thought to it, and before coming here this evening I felt that it was a very undesirable term. I think Mr. Fowle has shown very clearly the variety of ways in which that term may be interpreted and has been interpreted, and some of them seem very far afield. With reference to a private business, where it is the value of the service that is to be considered, the term is very likely to be used in a way that is not at all applicable to public utility cases, where it is becoming common to consider from the cost-of-service standpoint. To my mind the Wisconsin Commission's point of view or use of the term is one which is not justifiable; that is, if one wishes to consider the allowance for deferred profits or cost of developing business, he should use some other more suitable term than going value.

Mr. Williams, however, in his talk convinced me there was one way in which that term could be used that was quite proper, and that is in what is the real meaning of the words,—the cost or the value of "setting the business going." I suppose it is possible to use some other term for that particular meaning, such as *establishment value,* but the term *going value* seems really to apply in that case, the value of setting the business going. And having convinced me that it might be proper to use it in that case, Mr. Williams turned around and said he did not think it ought to be used there. So now I hardly know what we ought to call going value, although that seems to be the only use of the term which fits in with the real meaning of the words. With respect to public-utility rates, I think it would be best to avoid the term, and consider any elements which enter into it under their respective heads and on their respective merits.

J. R. Cravath, M. W. S. E.: There have been a number of criticisms of the Wisconsin Commission's methods this evening, but I feel that if the Wisconsin Commission's decisions have varied from those of the courts, it has been because they have been inclined to look at the thing more from the standpoint of square deal all around than from a purely legal or technical standpoint. Looking at it from the standpoint of the square deal, the Wisconsin Commission has recognized that the investor in these enterprises at the pioneer stages has a right to expect more than an ordinary return on the investment. At the same time, for the protection of the public, the investor has no right to demand a return on a foolish investment. If he has been unwise in putting his money into an enterprise which had little chance of success, that is his lookout. It is a business mistake and he will have to write it off to profit and loss.

Franklin H. Reed (Editor, Telephony): Mr. Fowle's paper has brought this subject before the Society in such admirable

form as to facilitate a grasp not only of the breadth of the problem, but of the diversity of judgment which has been exercised in the attempt to formulate measurement systems that will give a result susceptible of proof.

The engineer achieves success in proportion to the power of the embodiment of his plans to resist destructive forces, and promote progress. The closest estimation of the cost of rock excavation will not make a successful tunnel if the tubes running from opposite directions do not meet. One must ever have an eye to the future in a directive sense.

A plan for the measurement of going value must be so rigid as to resist efforts at distortion by those who hope to receive value without creating it—and yet interpose no barrier to the sound expansion of utilities.

The theories of going value have been formulated to meet the exigencies of judicial inquiry. A prime function of the courts is to look closely to the preservation of property value. The wise public seeks also the promotion of efficiency and, within economic limits, the increase of volume, of the services rendered by the public utility corporations.

If these suggestions hint at the true direction in which a sound theory of going value must lead the investigator, can it be said that any one theory reviewed in the paper will satisfy the conditions?

Do these theories tend to the utmost to promote highly efficient organization, for one thing? A group of investors wishing to create a public utility business must have funds in hand to cover more than the cost up to the time the plant is completed. They must take money from their own accumulated resources to pay for getting business and for operating the system up to the time the income exceeds the outgo. And the amount of funds they must so provide in advance for operating expenses varies, to some extent, inversely as the efficiency of the organization. Yet this efficiency, however difficult it may be to measure its cost value just hinted at, has a value that will stand the economist's test of exchange, and a value for the public. The price of a business sold will be higher if the new owners can take over an operating staff producing an efficient service at low cost; lower if the old men must be displaced by new. The public suffers at the hands of an inefficient organization and when it becomes cognizant of unfavorable conditions is willing to spend time, money, and effort—give value—to have the organization made more efficient . The elements in a concern that create a better service at a lower cost must eventually receive a price recognition from the public. Study of comparative unit costs may help toward this. These elements are not susceptible of capitalization. The New York commission has already hinted at allowing going value to influence the rate of return.

The engineer attempting to build up an estimate of the going value of any specific property, is confronted by difficulties in the shape of inadequate records and the necessity of evaluating information which may be heavily loaded with the "personal equation."

In this connection, the comparatively recent decision of the Oklahoma Supreme Court in the telephone case appealed by the Pioneer Telephone & Telegraph Company from the decision of the Oklahoma Corporation Commission, is very interesting.

The company's briefs embrace a very complete citation of previous cases before courts and commissions, which were fully reviewed by the Supreme Court, but in its opinion it places much stress upon the fact that the testimony of E. D. Nims, president of the company, of Engineer J. M. Noble and other officials, agreed in estimating for that particular case that the going value equaled about 20% of the reproduction cost.

The court seems thus to have been disposed to recognize that under the conditions which have prevailed in building up a property at a time when going value was not subject to discussion, and the desirability of proving its precise quantity was not foreseen, the scanty information which may be gleaned from the accounts is likely to be less reliable than the carefully considered judgment of men who know from experience how public utility enterprises are created.

Closure.

Mr. Fowle: I quite agree with Mr. Williams that there has been much confusion of terms and definitions, which throws additional difficulties around the discussion of a subject already complex. The thought came to me to attempt the preparation of a glossary of terms, but upon reflection I concluded that the subject needs more discussion; and furthermore I believe that such a glossary, to be of real use, ought to be the composite work of several minds coming to the subject from different individual viewpoints.

One of the statements made by Mr. Williams early in his discussion strikes me with particular emphasis—as follows:

> "There are but two fundamental methods of determining the value of a public utility. One is the cost method, which Mr. Fowle brought out very clearly, namely, the cost of construction plus the cost of developing the business. Under this method, economically speaking, there is no such thing as going value. The substitute therefor being development cost."

What I would emphasize in this statement is the frank concession that going value, in the sense in which Mr. Williams defines it, is wholly absent under the cost-of-service theory of rates.

He then goes on to say:

> "It is the identification of this with going value. that brings confusion, and causes trouble in valuations. Under this method, what is properly termed the plant investment, is determined by the cost of the plant, plus the cost of developing the business. This method has probably been presented by the owners of public utilities, in one form or another, to every court of the land that has heard a public utility valuation case. The other of the two methods consists in ascertaining the economic value of the plant, or the value of the investment, as distinguished from costs."

This appears to be a clear distinction between the ordinary definition of economic value, as it would apply in the value-of-service theory, and the cost definition; or, in short, it seems to me that it is equivalent to the statement already made in my paper that the reproduction of net earnings method of finding going value does not apply under the cost-of-service theory If I interpret Mr. Williams' language correctly, we are entirely in agreement on that point—which seems to be a very important one. But we evidently disagree on the question of cost-of-service versus value-of-service as a proper rate making basis.

This question as to the right basis for valuation and rate making is deeper and broader than the incidental matter of going value. Underlying the entire subject of rate regulation is the query—what are we trying to accomplish? The answer, from the standpoint of the best interests of all, is that we are trying to establish a square deal, or true justice, as between the investor and the consnmer. This makes it apparent that the valuation which we are seeking is the investment value. Briefly, then, we wish to know what comprises the fair and reasonable value of a public utility, as a going concern, to the investor.

The courts have recognized no single or infallible method of fixing this value. They admit as evidence the actual cost, the present cost of reproduction, and the amount of securities issued; but they lay down no definite or fixed rule. This is obviously wise and just, for each case presents its individual features and peculiar combinations of conditions, needing the most careful consideration and the exercise of a great deal of judgment in reaching a fair decision. It may often be the case when we have all the facts in hand, in a given instance, that actual cost is one thing, reproduction cost another thing, and the outstanding securities something else. Furthermore, there may have been consolidations, reorganizations and financial manipulations of one kind or another, all needing consideration.

But we can say with great certainty that the present tendency is to allow the investor all that his property, as a going concern, could reasonably cost. I am referring, of course, to the

sort of regulation which is conspicuous for its fairness to both sides Or, to put it in another way, the present tendency is undoubtedly to depart from the early value-of-service theory, founded upon competition, and to approach the cost-of-service theory, under local monopoly, with regulation.

I wish to take exception to Mr. Williams' use of the term "junk" theory of valuation as properly descriptive of the cost of reproduction less depreciation. As a matter of fact, the total present cost of reproduction, less the depreciation to date, gives the whole remaining service value, as part of a going concern. The junk value is only that value which remains after the service value is entirely extinguished, and in all ordinary appraisals the junk value is but a small fraction of the cost of reproduction less depreciation. I am referring, naturally, to tangible or physical property, in this connection.

The decision handed down by Judge Brewer in the Kansas City case, some eighteen years ago, appears to have been the inspiration for the reproduction of net earnings method of measuring the going value. Mr. Alvord quotes briefly from the decision, to emphasize the principle that in appraising a public utility which is in full operation, we must value it as a going concern. Everyone must admit this is absolutely sound; that is, between a utility which is structurally complete but not operating, and a similar utility which is in full operation, there is a material difference in value The question is how to measure this value. Under the cost theory it is the investment necessary to procure customers and set up a going business. But under the value theory it may be any one of several things, depending upon what we accept as defining and measuring value. In this connection Mr. Williams says:

> "If a public utility is worth more than the cost of reproduction because it has a business, it is worth more because of some part of the revenue it is going to produce in the future; otherwise no value could be realized by the purchaser in excess of reproduction value."

It seems to me this is capitalizing the future revenue or earnings and therefore not justifiable.

Mr. Alvord's dissent from my position that the net earnings have no separate value of themselves, which can be capitalized, and his analogy of the steam engine which confers abstract value on a plant of which it is part, is not, to my way of thinking, at all convincing. It would be wrong, certainly, to value the engine as physical property, and, on top of that, allow an abstract value which the engine confers on the rest of the plant because the plant could not operate without the engine. This would surely be giving it a double value. Again the parallel seems to fail because the engine is part of the capital or investment, while

earnings are not investment, but profits or returns on the investment. It is only when the profits exist that the investment has the value which we would assign to it under the cost theory of valuation. Without any profits, or with diminished profits, the value to the investor would certainly diminish. Profits are a necessary accompaniment of investment value; and when profits, by their existence, have created the investment value, they cannot be taken away and considered as creating a new and additional parcel of value, which augments the investment value already created.

The fact that it costs something to set a business going is well illustrated by Mr. Alvord's account of the case in which a certain city proposed to build a rival or competing water works. The cost is comprised of actual outlay to get customers and the loss of profits during the early period of operation. These outlays and losses, which have been termed going value under the cost theory, have, in a certain sense, a parallel in the going value which is found under the theory supported by Messrs. Williams and Alvord. The latter method I have termed the reproduction of net earnings, while Mr. Alvord refers to it as the value of a created income. This admittedly has nothing to do with the actual cost of setting a business going, but it measures the loss of income while the business is being re-established, under the supposition of reproduction of the entire plant and business, as of the present date. It is not difficult to see that this method is one way of estimating the loss of certain profits while the business is being established as a going concern. But as a practical matter it seems to produce a going value greatly in excess of what would be allowed under the cost theory.

The whole idea of reproduction, in valuation, is simply a convenient myth, because no one intends to reconstruct the property in actual fact. It is merely an assumption incidental to finding, not what the plant did cost, but what it probably would cost now, at the present day. We assume to wipe out the existing plant, in a mental picture, to facilitate the imaginary process of building it anew, exactly as it was before; or, put in another way, reproduction is only a device to aid in finding what the plant would cost now, instead of what it really cost in the past. There seems to me no logical reason for extending the reproduction idea to the entire business. But if it is logical, nevertheless, to carry the reproduction idea through to the end, ought we to stop there? Ought we not to wipe out the consumers and the whole community, and start over again with the original conditions? The last proposal seems quite absurd, of course, but it is the conclusion we are led to by a rigorous extension of the theory of reproduction.

As between two cities of like size and character, one with a paying utility in full operation and the other with none at all,

the investor would be likely to invest in the going concern instead of building a new utility in the other city—under equal conditions as to rates, franchises, regulation, etc. But the fact that the new utility would probably earn no profits at first is not a circumstance which makes the going concern of greater intrinsic value; instead of that, it causes the new utility to be worth less, as an investment, than its structural cost—until the business is entirely established and the deferred profits have been fully earned.

I am not in accord with the criticisms which have been offered here on the work of the Wisconsin Commission. In reviewing their decisions and comparing them with court decisions, we ought to keep in mind that the Wisconsin Commssion is administering the public utility law, which went into effect about four years ago, while the courts, in other states, have been guided by the general statutes and the common law. Thus the conditions are essentially different. The rules of law laid down by the courts are entitled to our greatest respect, but it is entirely possible that decisions handed down one or two decades ago are not consistent with newly arisen conditions and needs. Perhaps this is particularly true in relation to the tremendous growth of our public utilities in the past twenty years.

I confess to not having read the paper on the going value of water works, in the proceedings of the *American Society of Civil Engineers,* by Messrs. Metcalf and Alvord, but I infer from Mr. Alvord's remarks that it throws no further light on the fundamental questions we have been discussing.

The influence of a theory of going value—or its application—upon the efficiency of an operating organization, as suggested by Mr. Reed, seems to me rather remote. The thing we are really seeking, in our quest for an acceptable theory of going value, is justice—no one can fairly ask more, or less. An injustice to a utility company might do it severe harm, admittedly, affecting not only its organization but its whole existence and prosperity. This suggestion is much like the plea that good management is entitled to a valuation, because it produces better service than a poor or an indifferent management.

The abstract theory that management, good or bad, is an element of value to be taken into account in appraising a going utility, seems to me to have a parallel in the principles which govern men's conduct. Primarily, no person observes the laws of society because there is any direct reward or compensation which society as a whole will pay to him for so doing; on the contrary, society will punish him for disobedience of the law. So it is, I think, in regard to the management of a public utility; good and efficient management is very essential to the fullest success and earns its own reward, while poor management carries

its own punishment in the shape of diminished profits and possible failure.

Wise regulation places a fair and just value on the utility, as a going concern, and then allows a reasonable rate of return in the light of the risks involved and the general return expected upon similar risks, say seven or eight per cent. Where the principal risk is one purely of management and business administration, with great stability of market and prices, it would seem that capital ought to be attracted, with such a return. Those who think that the return ought to be greater are always prepared with arguments for higher rates of profit and large allowances for intangible value. Quite aside from the question of justice and a square deal, those who seek these ends should consider that their course leads toward ultimate public ownership of all utilities, in the interest of economy. We are probably all agreed, or nearly all, that such an end is very undesirable, at least under modern conditions, and it would be unfortunate in the extreme if it is brought upon us by the unreasonable though sincere demands for excessive returns.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Extra Meeting, January 22, 1912.

An extra meeting of the Society (No. 772), being a Joint Meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., was held Monday evening, January 22, 1912.

The meeting was called to order at 8:10 p. m., Mr. G. T. Seely, chairman, and about 80 members and guests in attendance.

The minutes of the preceding meeting of December 27, 1911, were read and approved.

On motion, the proposed amendments to Rules of the Electrical Section, submitted at the preceding meeting, were adopted. Also on motion, the Secretary was authorized to cast the ballot for the election of members of the Executive Committee for 1912, as follows:

P. B. Woodworth, Chairman.
James Lyman, Vice-Chairman.
G. T. Seely, Member of Committee for three years.

Mr. Robert J. Young was then introduced, who addressed the meeting on "The Prevention of Industrial Accidents." This was illustrated by many lantern-slide views, exhibiting protective devices.

Discussion followed from Messrs. W. E. Symons, B. I. Budd, W. L. Abbott, S. Montgomery, with replies and explanations from Mr. Young.

A vote of thanks was tendered the speaker for his address.

Mr. Abbott then stated that the Commonwealth Edison Co. had procured an oxygen rescue apparatus to revive suspended respiration due to electric shock or gas inhalation. This pulmotor apparatus was shown and explained by Mr. P. B. Junke, of the Commonwealth Edison Co.

Meeting adjourned about 10:20 p. m.

Extra Meeting, January 29, 1912.

An extra meeting of the Society (No. 773) was held Monday evening, January 29, 1912.

The meeting was called to order about 8:15 p. m., Vice-President Bement presiding, with about 95 members and guests in attendance, including many ladies.

Mr. C. M. Strieby was introduced, who addressed the meeting on "An Automobile Factory in Action." With lantern slide and moving picture illustrations, the speaker showed two large automobile factories, and the processes of manufacture, particularly in the fabrication of parts of iron and steel.

Meeting adjourned about 10 p. m.

Regular Meeting, February 5, 1912.

A regular meeting of the Society (No. 774) was held Monday evening, February 5, 1912. The meeting was called to order at 8:20 p. m., President Armstrong presiding, and about 70 members and guests in attendance.

The Secretary reported from the Board of Direction that the following had been elected into membership:

Arthur Barton Glenn, Champaign, Ill...............Student Member
G. W. Hebblewhite, Chicago, transferred to.........Associate Member

Charles Francis Harding, West Lafayette, Ind........Member
Fritz Balzer, Chicago..............................Associate Member
Bernhard Schroeder, Chicago, transferred to........Associate Member
Arthur L. Webster, Wheaton, Ill....................Member
Forrest Shepherd Harvey, Chicago, transferred to....Associate Member
Russell Burns Easton, Aberdeen, S. D...............Associate Member
John A. B. Tompkins, Milwaukee, Wis................Member
Axel K. S. Sjolander, Chicago, transferred to.......Member
Herman P. Andresen, Chicago.......................Member

Also that the following had applied for membership:

Frederick F. Shafer, Springfield, Mo.
Elmer Juergens, Chicago.
James S. Harvey, Chicago.

The following resolution was presented, which was duly ordered:

"In consideration of courtesies extended the Western Society of Engineers at the time of their Annual Meeting held in January of this year,

"Be it Resolved, That a vote of thanks of the Society be given to the following:

"Chicago, Burlington & Quincy R. R. Co., Mr. F. E. Ward, General Manager.

"Illinois Central R. R. Co., Mr. W. L. Park, Vice-President and General Manager.

"International Harvester Co., Mr. John G. Wood, Western Superintendent.

"American Bridge Co., Mr. August Ziesing, President.

"The Pullman Company, Mr. John S. Runnells, President."

There being no other business to bring before the meeting, Lieutenant-Colonel George A. Zinn, U. S. Engineer Corps, was introduced, who presented his paper on "The Chicago Waterways in Their Relation to Transportation."

Discussion followed from Messrs. Ernest McCullough, F. E. Davidson, Charles Campbell, H. J. Fixmer, W. E. Symons, C. B. Lewis, H. H. Evans, and J. A. B. Tompkins, with a closure from Colonel Zinn.

Meeting adjourned about 10:15 p. m.

Extra Meeting, February 12, 1912

An extra meeting of the Society (No. 775), being a meeting of the Bridge and Structural Section, was held Monday evening, February 12, 1912.

The meeting was called to order at 8:15 p. m. by Mr. F. E. Davidson, chairman, with about 90 members and guests in attendance. There was no business to be considered, so the chairman announced the subject for the evening's discussion, namely, "Assembling and Reaming of Structural Work." Mr. W. H. Finley opened the discussion and was followed by Messrs. H. E. Horton, C. F. Loweth, John Brunner, F. E. Davidson, W. C. Armstrong, Andrews Allen, S. T. Smetters, James Lister, J. H. Heuser, Ernest McCullough, H. W. Rutherford, E. A. Balsley, W. M. Hughes, J. G. Kreer, W. W. Curtis, G. Niestadt, with a summing up by Mr. Finley.

The meeting adjourned at 10 p. m.

Extra Meeting, February 19, 1912.

An extra meeting of the Society (No. 776) was held Monday evening, February 19, 1912. The meeting was called to order at 8:30 p. m., Past President Chamberlain presiding, and with about 60 members and

guests in attendance. There was no business to bring before the meeting. Mr. Linn White, M. W. S. E., Engineer of the South Parks, was introduced, who read his paper on "The Wearing Surface for Boulevards and Streets of Light Traffic." Mr. A. C. Schrader, M. W. S. E., Engineer for the West Parks, followed with his paper on the same subject. Mr. L. Kerschbaum, assistant to Mr. Schrader, followed, and read his notes relating more particularly to the hydrocarbon and bituminous materials made use of in park road work. Others who discussed the subject were: Messrs. Edwin Hancock, J. G. Gabelman, P. E. Green, and Mr. Chamberlain, with a closure by Mr. White.

On motion, a vote of thanks was returned to the gentlemen who had contributed such valuable papers, and on such short notice.

Meeting adjourned at 10:15 p. m.

J. H. Warder, Secretary.

BOOK REVIEWS

Strength of Materials. By James E. Boyd, M. S., Professor of Mechanics, the Ohio State University. Published by the McGraw-Hill Book Company, New York, N. Y. Cloth; 6½ by 9¼ in.; 295 + XII pp.; 199 figs.; XV tables in text. Price, $2.50 net.

In the preface the author states that this book is intended to give students a grasp of the physical and mathematical ideas underlying the mechanics of materials, together with enough of the experimental facts and simple applications to sustain the interest, fix the theory, and prepare them for the technical subjects as given in works on machine design, reinforced concrete, or stresses in structures. It is assumed that the reader has completed Integral Calculus and has taken a course in Theoretical Mechanics which includes statics and the moment of inertia of plane areas.

This is, therefore, a college text book and an exceedingly good one of its kind, but not easy reading for those who have neglected to keep up their knowledge of calculus and theoretical mechanics. It is one of a class of books becoming numerous and which seem to be publications of teachers' lecture notes and generally arranged to fit in as a portion of an engineering course pursued at the institution where the author is employed. M.

Geodetic Surveying and the Adjustment of Observations (Method of Least Squares). By Edward L. Ingram, C. E., Professor of Railroad Engineering and Geodesy, University of Pennsylvania. Published by McGraw-Hill Book Company, New York, N. Y. Cloth; 6½ by 9¼ in.; 389 + XX pp.; 92 figs.; X tables; bibliography. Price, $3.00 net.

The author states that he prepared this book because it was impossible to find a satisfactory text from which to teach the civil engineering students in the University of Pennsylvania such fundamental principles of geodetic surveying and the adjustment of observations as it was felt this class of men should be taught. The professional geodetist has plenty of satisfactory books to read, so this book is intended solely for engineering students and such civil engineers as may require to know something about geodetic work.

The fundamental operations of geodetic surveying are triangulation and precise leveling. These in turn require the determination of time, latitude, longitude, and azimuth; the determination of mean sea level; and a knowledge of the figure and dimensions of the earth. This book is divided into two parts and the first part satisfactorily covers such points on the above subjects as are likely to interest civil engineers. All measurements are subject to error and the second part of the book deals

with the application of the method of least squares to the adjustment of observations. The book is well written and should serve as a most satisfactory text-book in this very special sort of work, which seldom falls to the lot of engineers not in the employ of the government of some country. M.

SEWAGE SLUDGE. Treatment and Utilization of Sludge, by Alexander Elsner. The Drying of Sludge, by Fr. Spillner. Operation of Mechanical Sewage Plants, by Fr. Spillner and Mr. Blunk. Sludge Treatment in the United States, by Kenneth Allen. McGraw-Hill Book Co., New York. 1912. Cloth; 6 by 9 in.; illustrated; pp. 272; XLII tables. Price, $2.50.

In this volume Mr. Allen and Mr. Kuichling have brought together several foreign articles on sludge and the operation of sewage plants which are well worth studying. In addition Mr. Allen has made a compilation of some noteworthy examples of sludge treatment in the United States, a study which by its diversity and the amount of data available furnishes quite a contrast to the careful and thorough work done by the Germans. This is no reflection on Mr. Allen, but it is a distinct point which the operating men of the United States should try to improve.

In the articles on the treatment and utilization of sludge by Mr. Elsner, and on the drying of sludge by Mr. Spillner, the entire subject is discussed in a very thorough manner, with references to practice not only abroad but in the United States, with cost figures which are of interest to the American engineer even though they are not comparable with the American practice. The article on the operation of mechanical sewage plants is very timely and thorough, and gives a full description of the operating results in the Emscher district.

Mr. Allen has made a useful compilation of much scattered data bearing on the sludge problem in the United States, bringing out the diversity of practice.

The book is authoritative in tone, and should be read by all engineers who wish to become posted on the sludge problem. It is also of service to those people who come in contact with the many fanciful schemes for sludge treatment, to convince them that the value in sludge is, in general, as evanescent a dream as the extraction of gold from sea water.

L. P.

LIBRARY NOTES.

The Library Committe desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

Bion J. Arnold, M. W. S. E.:

Report on the Traction Improvement and Development within the Providence, R. I., District. Pam.

Milwaukee Bureau of Economy and Efficiency:

Plumbing and House Drain Inspection. Pam.
Water Works Efficiency. Pam.

C. L. Strobel, M. W. S. E.:

Reports of National Monetary Commission. Pams.

Virginia State Library:

Finding List of Books in Service. Pam.

McGraw-Hill Book Co.:
    Sewage Sludge, by Elsner, Spillner and Allen. Cloth.

E. E. R. Tratmen, M. W. S. E.:
    Proceedings of Ohio Engineering Society, 1911. Pam.
    Report on Water Works Extension, Kansas City, Kan. Pam.
    Association of Ontario Land Surveyors, Annual Report, 1911. Pam.
    Proceedings, Indiana Engineering Society, 1911. Pam.
    Report of Chief Commissioner, New South Wales Government Railways and Tramways, 1911. Folio.
    Locomotives and Rolling Stock at Brussels Exhibition. Paper.

C. W. Brooks, Assoc. W. S. E.:
    Seventy-four numbers of Journal, W. S. E.

D. H. Maury, M. W. S. E.:
    The Water Works System of the City of Chicago, Maury. Pam.

John Ericson, M. W. S. E.:
    Report on Creosoted Wood Block Pavements. Pam.
    Address before Committee on Local Transportation. Pam.

Chicago Bureau of Public Efficiency:
    The Judges and the County Fee Offices. Pam.
    The Park Governments of Chicago. Pam.

Universal Portland Cement Co.:
    Bulletins, 1911. Flexible cloth.

The Macmillan Co.:
    Laboratory Problems in Physics, Jones and Tatnall. Cloth.
    Storage Batteries, Harry W. Morse. Cloth.

H. W. Lee:
    Chicago Harbor Needs (Lake Calumet Harbor Plan). Pam.

A. M. McPherson, Boise, Idaho:
    Journal, Idaho Society of Engineers, May, 1911. Pam.

Allen & Garcia Co.:
    Catalogue, 1912. Pam.

EXCHANGES.

Illinois State Mining Board:
    Annual Coal Report, 1911. Cloth.

American Electrochemical Society:
    Transactions, 1911. Pam.

University of Wisconsin:
    Bulletin No. 466. Tests on Reinforced Concrete Columns. Pam.
    Bulletin No. 450. An investigation of the Air Lift Pump. Pam.

University of Illinois:
    Bulletin No. 51. Street Lighting. Pam.

Swedish Engineering Society, Chicago:
    Proceedings, December, 1911. Pam.

Tennessee Geological Survey:
    The Resources of Tennessee. Pam.

Institution of Engineers and Shipbuilders in Scotland:
    Transactions, 1910-1911. Cloth.

Master Car Builders' Association:
Proceedings, 1911. Cloth.

Canada Department of Agriculture:
Report of Dominion Chemist, Central Experiment Farm. Pam.

Indiana Sanitary and Water Supply Association:
Proceedings, 1911. Pam.

Pennsylvania Department of Agriculture:
Monthly Bulletins, October, November, 1911. 2 Pams.
Tabulated Analysis of Commercial Fertilizers. Pam.

Illinois State Water Supply Association:
Proceedings, 1911. Cloth.

Manchester, N. H., Institute of Arts and Sciences:
Proceedings, Vol. V., Part I, 1911. Pam.

Institution of Naval Architects, England:
Transactions, 1911, Part II. Cloth.

GOVERNMENT PUBLICATIONS.

Smithsonian Institution:
Annual Report, 1910. Cloth.

U. S. Bureau of Education:
Bulletins 13, 16, 1911. Pams.

U. S. Department of Agriculture:
Eulogical Studies. Pam.
Experiment Station Record, November, December, 1911. 2 pams.

MEMBERSHIP.

Additions.

Andresen, H. P., Chicago....................Member
Balzer, Fritz, Chicago....................Associate Member
Easton, Russell B., Aberdeen, S. D....................Associate Member
Harding, C. Francis, Lafayette, Ind....................Member
Tompkins, John A. B., Milwaukee, Wis....................Member
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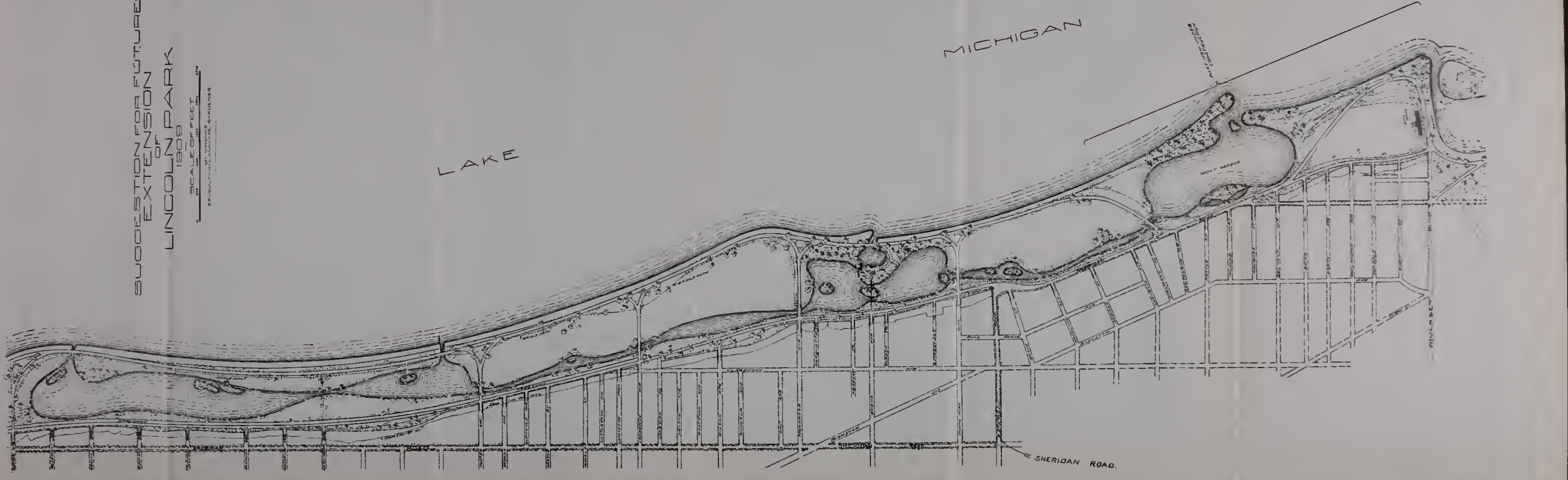
A. Bement—Use of the Great Lakes

Plate I



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THE CELILO BRIDGE

Ralph Modjeski, M. W. S. E.

Presented before the Bridge and Structural Section January 8, 1912.

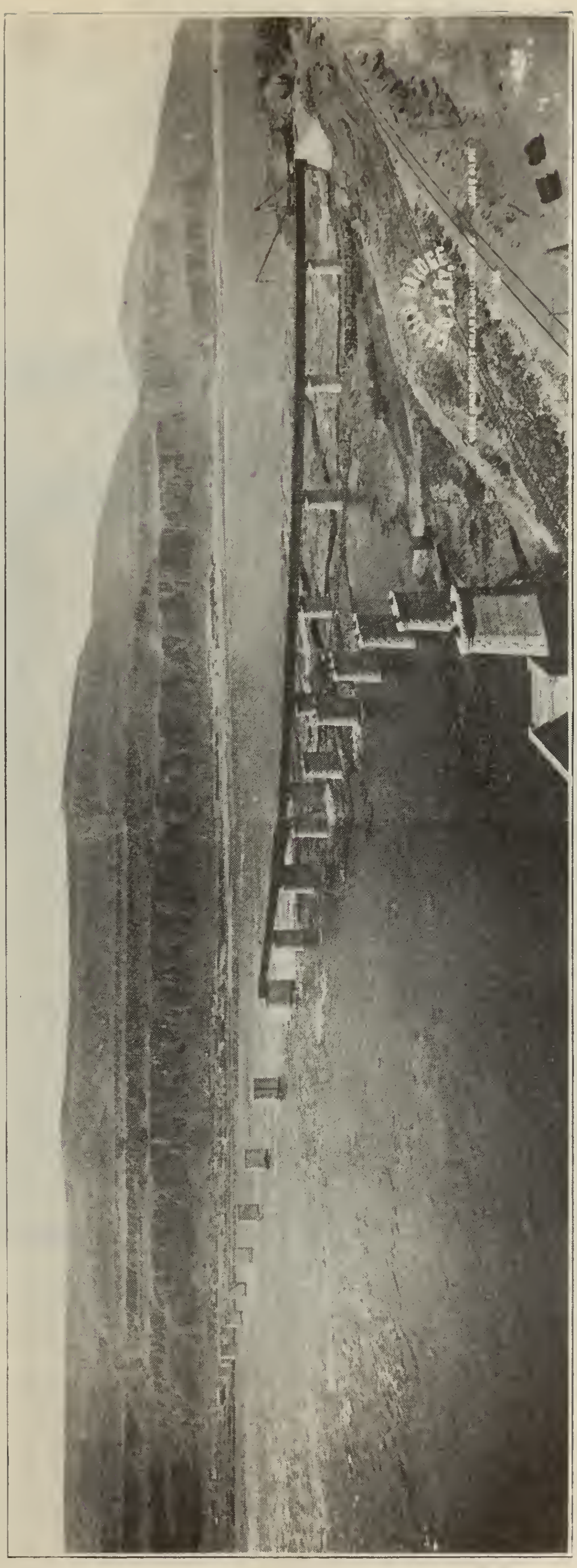
Following up the Columbia River for about 100 miles from Vancouver, Washington, and crossing over to the Oregon shore, we might be able to find a small town called Celilo. The formation of the bed of the stream at this point is most unusual and interesting. The river narrows down to a width of approximately 2,700 feet from shore to shore at high water and there are high basaltic bluffs on either side forming quite a narrow and picturesque gorge. At low water the bed of the river consists of a number of basaltic islands, separated by channels of rushing, roaring water. Each one of these channels taken separately and placed in any part of the middle states would form quite a curiosity and attraction for tourists. The main channel near the Oregon shore is about 300 ft. wide, while the other channels vary in width and are quite narrow, some of them drying up entirely during low water. As the water rises in the river, more and more of the small channels fill up until at high water, which happens once a year, all the islands are entirely submerged.

About two years ago, when the construction of the Oregon Trunk Line was begun, Mr. John F. Stevens, then president of that road, selected this spot, as well as another one about ten or twelve miles farther down stream near The Dalles, Oregon, as the two most favorable crossings to accommodate this road and connect it with the Spokane, Portland and Seattle Railway. The Oregon Trunk Line follows up the DesChutes River, whose mouth is only a short distance above Celilo, while the Spokane, Portland and Seattle Railway runs along the north, or Washington, shore of the Columbia River. The latter road is sometimes called The North Bank Road. The writer was engaged about that time to assist in deciding on the crossing and to take charge of the construction of this bridge as well as all other structures along the Oregon Trunk Line. It was then decided to use the Celilo crossing as providing not only the shortest haul for the Cregon Trunk Line but the cheapest bridge.

The bridge as constructed consists of 2,110 ft. of plate girder spans, six riveted through spans, 230 ft. center to center of piers, one draw span, 240 ft. long, and one pin-connected through span over the main channel 320 ft. long, center to center of piers. The north plate girder approach forms a *Y* so as to connect with the Spokane, Portland and Seattle Railway in both directions. The total length of steel work in the crossing for either the east or the west bound traffic is 3,246 ft., and the total length of steel work, including both legs of the *Y*, is 4,062 ft.

River Bed During Low Water.

The number of islands and channels and their irregularity furnished quite a study for the proper selection of the crossing, and several trials had to be made in the immediate vicinity before the final location was decided upon. Unfortunately no favorable location could be found at this place which would enable the crossing of the main body of the river at right angles to the current at high water, and therefore a slight skew had to be contended with. On the other hand, the location selected allowed an arrangement of the spans by which six of the through spans between the main channel and the beginning of the *Y* could be made of equal length, each pier being placed on rock above ordinary low water, making the foundation problem quite easy. Thus we have an unusual bridge, where all foundations of the river piers may be seen and examined each year. To speak more



General View of Celilo Bridge Under Construction.

correctly, the foundations have been built above low water by Nature, and it only remained for the engineer to place the piers on those foundations, thus saving all expensive foundation work.

The north pier of the main channel span is placed on a small island. This island being near the deepest portion of the river gave rise to some apprehensions as to its stability. In

Method of Erection, Adjustment Device Between Spans and Over the Pier at the Right.

order to ascertain that the island has not been undermined but rests on a solid foundation, three borings were taken thereon and other borings were taken on the opposite side of the channel near the water's edge. These borings extended 200 ft. below low water. A stratum of sand, or what the writer believes to be cinders, approximately 4 ft. thick, was encountered in all borings

at a depth of about 110 to 124 ft. below low water on both sides of the channel, but no overhang or undermining was shown. The behavior of the water in the drill pipe indicated that there is no communication with the main body of the water and is therefore

Erecting Through Span with Derrick Car and by Cantilever Method.

below the bed of the main channel. At that time it was considered impractical to take soundings in this channel owing to the swiftness of the current and inaccessibility of the location.

These will be taken now from the span. It was therefore considered safe to place a pier on the island.

It was at first contemplated to build all river piers of granite with concrete backing, but the cost proving to be excessive, the piers were built of concrete with granite nosings, belting, and coping, while the approach piers on the south side are all of concrete.

The design of the superstructure presents no features of unusual interest. It was proportioned to carry a loading of two 188.5 ton engines followed or preceded by 5,000 lb. per lineal foot for trusses, and one engine weighing 214.5 tons, with the same uniform load for the girders, floor system, and hip verticals. Liberal allowance for impact and excess load from the down throw of the wheels provides a large margin for increase of train load in the future. The bridge is a single track structure. The trusses are placed 18 ft. centers, leaving a horizontal clearance of 15 ft. 7 in.

As will be seen in what follows, some of the shorter spans as well as the channel span had to be erected by cantilever method, which made it necessary to fix the distance center to center of trusses uniform for all other spans.

The six 230 ft. spans are riveted throughout. The channel span for convenience and speed of erection has been made pin-connected, eye-bars being used in diagonal and bottom chords. Mention has been made of speed of erection. This will be better understood when it is known that there is no windier place than the Celilo gorge. The wind blows not only with extreme violence, but carries with it the fine Columbia River sand, making it almost impossible at times to work outside, and when the wind blows goggles become a necessity. At such times erection work, if possible at all, becomes dangerous. It appeared to the writer that the shorter time the projecting cantilevers of the incomplete channel span are exposed to such gales, the safer it would be. It was therefore deemed best to use pin-connected trusses for this span and cut down the time for assembling as much as possible.

Placing of false work in the narrow channels occupied by rushing water was out of the question. The spans were therefore so designed that they could be erected by cantilevering out over such channels until false work on the further side could be reached. Special erection devices were designed, consisting of temporary riveted tension members to be inserted between the hip joints of two adjacent spans. A span already erected could then act as anchorage to the one being erected. Wedges were provided in these temporary members; they had a pitch of one in six, and were lubricated with graphite and tallow.

This method proved very successful, especially in conjunc-

tion with the use of a derrick car for erecting the trusses. The writer must admit that before the erection of the trusses was begun he was strongly prejudiced in favor of the traveler method of erection, but that as the work progressed and as the derrick car was being employed he became more and more convinced that for moderate spans the traveler will soon be superseded by the derrick car or a similar tool. The last four 230 ft. spans were erected with two derrick cars, one setting out false work and the other following and erecting the steel. From the nature of things the false work could not be built much ahead of the steel without great expense in handling timber across the channels. The time

Erecting Plate Girder Spans on Wye.

consumed in the erection of the six 230 ft. trusses from the placing of the first bent of false work was one hundred days, or an average of about sixteen and one-half days to the span. This, of course, includes false work, and also many windy days in which no work could be done. The first span took about three weeks to assemble, while some of the other spans took considerably less than sixteen days.

The 320 ft. channel span was the last one to be erected. The south approach girders and the draw span were erected before all of the 230 ft. spans were connected up. It was contemplated to erect the south half of the channel span by means of a traveler, then take down this traveler, move it across the

channel, and erect it for the north half of the span. Stringers were suspended crosswise at panel points to carry the traveler track outside of the trusses. Several panels of the south half of the span were erected in that way, but just before the erection of this span was commenced, an error in the assumptions in the calculations of the erection stress affecting especially the top chord ot the draw span, was discovered, which resulted in a change of the method, and, strange to say, hastened the completion of the work by at least two weeks. This error was caused by underestimating the overturning load of the traveler, due to the high winds. The results, taking into account all wind stresses, showed

Erection of Main Chanel Span by Use of Derrick Car.

a stress of 24,000 lb. in tension in the end panel of the draw span top chord; also other stresses slightly above 20,000 lb. While theoretically the stress of 24,000 lb. is well within the elastic limit,—which in this material is not less than 35,000 lb. per sq. in.—practically it was much too high. Erection was therefore started by means of the traveler, with the understanding that it would not go out as far as originally contemplated, and that many of the less important members in the four center panels would be left out and not put in place until after the removal of the traveler. In the meanwhile the mind of the contractor's foreman, Mr. Kelly, was working and as a result, the traveler was taken down and not used at all on the north half. Instead of that the erection was completed with a derrick car in a most

successful way. The saving in time is represented by the time required to remove the traveler, ship it across the river, and rebuild it; or even if two travelers had been used, the time saved would have been considerable. This is another defeat for the traveler method in favor of the derrick car. The center connection was made by slacking the wedges in the temporary top chords, the bottom chord connection being made first. A wedge adjustment was also provided at the shoes between the north end of this span and the adjoining one, but no adjustment was deemed necessary at the south end, which simply butted against the shoes of the draw span.

The progress of the work was as follows: Engineers' camp was established in February, 1910. The ground for foundations was broken July 9th, 1910. The substructure was completed on June 5th, 1911. So that the total time consumed by the substructure was eleven months. The first steel in the shape of girder shoes was erected April 20th, 1911, and the first train crossed the bridge January 4th, 1912. The time consumed in erection and in getting the track ready for traffic was eight and one-half months, and the total time of construction from the breaking of the ground to the opening of traffic was seventeen and one-half months.

APPENDIX.

OREGON TRUNK RAILWAY SPECIFICATIONS.

UNIT STRESSES.

In the following:

D.L.=dead load.

R.L.=rolling load.

L=length of span.

d=distance covered by load to produce maximum stress.

E=excess load.

U=unbalanced load.

l=length of member in inches.

r=radius of gyration.

ROLLING LOAD.

Two 188.5 ton engines followed by 5,000 lb. per lin. ft., or

One 214.5 ton engine followed and preceded by 5,000 lb. per lin. ft.

The one giving the greatest result to be used.

The following unit stresses in pounds per square inch to be used:

1. Chords in compression and end posts,

D.L., 18,000

R.L., 9,000

Least transverse dimension not to be less than 1/16 of the unsupported length; portion of top cover plate unbalanced by bottom flanges not included in determination of section.

2. Combined R.L. + D.L. + Wind stresses in end posts not to exceed 15,000 lb. per sq. in.

3. Web members in compression,

$$\text{D.L., } 20{,}000-80\frac{l}{r}$$

$$\text{R.L., } 10{,}000-40\frac{l}{r}$$

4. All tension members except hangers,

D.L., 20,000
R.L., 10,000

(3 and 4) R.L. to be increased by $E = \frac{L-d}{L+d}\%$

5. Hangers and members subject to sudden loading,

D.L., 16,000
R.L., 8,000

6. Compression members receiving direct stress from (5),

$$\text{D.L., } 18{,}000-72\frac{l}{r}$$

$$\text{R.L., } 9{,}000-36\frac{l}{r}$$

(5 and 6) R.L. to be increased by $U = 1/3\ (100-L)\%$.

ALTERNATE STRESSES.

7. 1st. Compression alone not to exceed unit (3) for live load.

2nd. Calculate sections required for tension at 10,000 lb. per sq. in., and compression at 14,000 lb. per sq. in., and add 75% of smaller section to the larger one.

3rd. Tension alone not to exceed unit (4) for live load.
Total area in member to fill the above three conditions.

8. Flanges of girders 100 ft. span or less, floor beams and stringers,
D.L., 20,000
R.L., 10,000 to be increased by U = 1/3 (100—L)%

9. Shear in webs,
D.L., 12,000
R.L., 6,000

10. RIVETS.

	Shear	Bearings	
D.L.	12,000	24,000	Add 20% for field driven.
R.L.	6,000	12,000	

Rivets in members subject to reversal of stresses to be proportioned for the sum of both stresses.

11. PINS.

	Shear	Bearings	Bending
D.L.	15,000	30,000	30,000
R.L.	7,500	15,000	15,000

Pin bearing in members subject to reversal of stresses to be increased at least 50% over what is required for maximum stress.

12. Lateral stresses may be 50% greater than R. L. stresses.

13. Pressure on masonry,
D.L., 500 lb. per sq. in.
R.L., 250 lb. per sq. in.

14. Rollers,
D.L., 500 D per lineal inch of roller
R.L., 250 D per lineal inch of roller
(where D equals diameter of roller in inches.)

Discussion.

John Brunner, M. W. S. E. (Chairman): We are under great obligations to Mr. Modjeski, a Past President of this Society, for presenting to us this interesting paper on the Celilo bridge, and exhibiting such good illustrations.

The paper is now open for discussion.

I. F. Stern, M. W. S. E.: In regard to the substitution of the derrick car for the traveler, I have favored that idea for a long time, and the C. & N. W. Ry. Co. has succeeded in converting many of its contractors to that same point of view. In fact, the traveler as used at the present time is simply a development of the derrick car. I remember very distinctly, in going over the erection of the Queensborough bridge—or Blackwell's Island

bridge as it is often called—that the travelers there were simply a development of derrick cars running on a curved track. The traveler that moved forward was used, and on top of the traveler was the mast; as this was pushed forward, they really had the derrick car action on that. So I think we are really coming to the point, as suggested by the author, where the derrick car is superseding the traveler.

Edward Haupt, ASSOC. W. S. E.: With reference to the derrick car operation, I can supplement what the author and Mr. Stern have said. About six years ago the company with which I am connected used derrick cars for taking down and rebuilding

Derrick Car Wrecked by Wind.

a bridge. There was a good deal of opposition on the part of our construction superintendent, because he wanted to hold to the old-fashioned way of doing it by travelers. The traveler runways and camber blocks had all been put in, but we concluded to try the derrick car method and it worked out so successfully that we have used that method ever since. In Buffalo, in putting up a double track swing bridge we constructed two independent derrick cars, operating on tracks running out from the drum. This method also worked out very satisfactorily.

Mr. Stern: It occurred to me, in looking at the illustrations of this paper, that in some of the cases another method might have been used, and I want to ask if the author considered using

temporary deck plate girders to span some of the short openings. Erection has been done that way. I recall one case where we had to go over a double track railroad. We could not put in false work there for 50 or 60 ft., so we put up a deck plate girder span, or a couple of deck plate girders, and erected the bridge about 5 ft. higher than the final position, and then lowered it.

Mr. Modjeski: Certainly that could have been done, and it was considered in the cases of some of the narrower channels.

Erecting Plate Girders on the Wye.

Some of the channels were not narrow enough to span by 100 ft. girders, which we had on hand; but after consultation with the contractors for erection, they adopted the cantilever method throughout. They would have had to use that method in some places, and they thought they might as well use it throughout. That is the reason why it was employed.

F. E. Davidson, M. W. S. E.: I would ask the author if any observations were made of the actual wind pressures under these

unusual conditions. The subject of wind pressures is one in which I have always been much interested. One illustration showed that the wind had overturned the derrick car. It occurs to me that the pressure per square foot upon the sides of the big plate girders might have been approximated by measuring the pull on the guy ropes while swinging the girders into position.

Mr. Modjeski: No experiments were made to determine the wind pressures.

Mr. Davidson: The author referred to the Crooked River arch bridge, and stated that the arch was designed as a three-hinged arch for dead load and a two-hinged arch for live load. Is that method of designing something new or unusual, and why was it adopted for that arch?

Mr. Modjeski: As far as I know, the method is entirely new. I did not speak of it as extensively as I might have done, as I want to include that matter in another paper.

Mr. Stern: Recently I read an article in one of the engineering papers relating to the "Soo" arches, in which the same claim is made, and the device being completed is shown.

There are alternate plates of bronze and steel, connected with many pins. Under dead load they will move, or at least the claim is that they will move, so that there is a three-hinge action, while under live load they are binding to hold, so there is only a two-hinge arch.

Mr. Modjeski: This case is not similar and I will explain it. The arch is figured as a two-hinge arch for dead load at a certain temperature—we will say 60°. Before placing the last piece of the top chord in the center, the arch was loaded so that it would carry its dead load assumed in the calculations and a proper temperature was observed. The center member of the top chord was then marked and subsequently drilled to that proper length and riveted up, so that at 60° temperature with no live load on it there is no stress in that center top chord member. The arch is assumed then as a two-hinge arch in carrying live load stresses and temperature stresses.

Mr. Brunner: About fourteen years ago I designed and erected two-hinged plate girder arches in Pittsburg for one of the street bridges, and found that under the dead load at a certain temperature no stresses existed in the upper flange of the plate girder arch. We erected the bridge and connected up the bottom flange; then we let the bridge stand until the temperature dropped to the point at which our figures showed that there would be no stresses in the upper flange. We then connected up the top flange and riveted the center connection.

R. G. Lawry, M. W. S. E.: What wind loads were used in figuring the trusses in this bridge?

Mr. Modjeski: That information can be found in the stress sheets to be published with this paper.

F. G. Vent, M. W. S. E.: What kind of paint was used?

Mr. Modjeski: Mammolith Carbon paint was used, the same kind that was used on the Columbia River bridge at Vancouver, but we had no sand there. The Vancouver bridge was painted with three kinds of paint; different sections of the bridge were painted with different paints. The Mammolith paint remained softest after nearly two years; it was thought it would be better here than a harder paint, on account of sand. At the same time it

Channel Between Piers VII and VIII.

was only a conjecture, and I do not know how it will work out. There is one thing to be said—where the paint will be destroyed by sand the surface will remain polished by sand blast, so that will take care of itself.

C. A. Budd, M. W. S. E.: At the Columbia River bridge on the Chicago, Milwaukee & Puget Sound Ry. one of those registering wind gauges was used, but it was found that the gauge did not commence to register until the wind had blown probably for five or ten minutes. As the high wind sometimes lasted only five or ten minutes, the machine would just commence to register as the wind went down. So the gauge at that place was of little value.

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Fig. 1.


DES MOINES RAPIDS CANAL
CANAL
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RIVER
ILLINOIS
IOWA
DES MOINES RAPIDS
DES MOINES
MISSISSIPPI
N.
U.S. GOV'T. LOCKS
POWER HOUSE
FRANKLIN
FULTON
MORGAN ST.
NEW ST.
CONCERT
MAIN
FIRST
WATER
BROADWAY
OAK ST.
LAUREL ST.
TO HAMILTON
MISSISSIPPI RIVER POWER CO.
HUGH L. COOPER, CHIEF ENGINEER
GENERAL CONSTRUCTION MAP
SHOWING LOCATION
OF
PERMANENT WORKS
AND
CONSTRUCTION LAYOUT
USED IN THE BUILDING THEREOF.
DRAWING NO. 1851
CORRECTED TO OCTOBER 1, 1911

Fig 1

THE WATER POWER DEVELOPMENT OF THE MISSISSIPPI RIVER POWER COMPANY, AT KEOKUK IOWA

Abstract of an Illustrated Address by Hugh L. Cooper.*

Presented before the Hydraulic, Sanitary, and Municipal Section, October 18, 1911.

There is now under construction on the Mississippi River between Keokuk, Iowa, and Hamilton, Illinois, the largest hydro-electric plant in the world. This power will be developed by using the entire flow of the Mississippi River under an average working head of about 34 ft.

The dam is being built at the foot of the Des Moines Rapids, and back water from the construction of the dam will extend north about 65 miles and create a lake about 100 square miles in area. This work is being built on the bed of the river, on the authority of the United States Congress, as it is largely in aid of navigation.

The length of the dam, including the power house and locks, is 9,096 ft., of which length the power house is about 1,750 ft.

The total power developed will be 200,000 horse power delivered to the customers, and the generating station capacity of the plant will be 340,000 mechanical horse power .

In the financing of this work it was necessary to secure some contracts in advance in order to demonstrate the ability of hydro-electric power to compete with cheap coal in this territory. Contracts were therefore made to furnish the utilities of St. Louis, over transmission lines about 140 miles long, 60,000 horse power under a 99 year contract. Other transmission lines are contemplated to the north of Keokuk, and with branch lines to other territory as later investigations show necessary.

A general plan of the construction layout is shown in Fig. 1, and from this plan it will be observed that the work is progressing in all of its divisions and branches as rapidly as possible. The completion date is set for July 1, 1913, which made it necessary for special preparations to be made in the construction campaign.

All of the work is being done by administration under the direction of the Chief Engineer, and no work is being done by contract. This plan has not been dictated by any differences or dislikes to contractors, but rather from the necessity for special speed and the use of special equipment not to be found in possession of any contractor.

The operating head will vary from 39 ft. in times of extreme

*Vice-President and Chief Engineer, Mississippi River Power Company, Keokuk, Iowa.

low water to 22 ft. in times of extreme high water. The normal power of the turbines has been figured for about six-tenths gate opening, so that as the head decreases in times of high water the speed of the wheels may be maintained by opening the gates full without too great a loss of power.

It is figured that the turbines will develop about 7,200 horse power at the low head of 22 ft.

The main dam across the river will be 4,570 ft. in length, and consists of a concrete spillway, surmounted by a concrete arch bridge superstructure.

There are 119 openings between the arch spans 30 ft. in the clear, which in times of low water may be closed by sliding gates operated by traveling gantrys on top of the spillways. These gates are 11 ft. high and 30 ft. wide in the clear, and will be built of structural steel. The purpose of these gates is to maintain the highest possible water levels in the pool at all seasons of the year. At times of high water the number of gates discharging will be regulated by the quantity of water approaching the structure, and as the quantity recedes the gates will be closed; the general operating campaign will never cause the level of the pool to change more than 3 ft. below El. 525.00.

The foundations for the dam are all of solid rock, and the entire structure from one end to the other is founded on undisturbed, close-grained, closely-laid limestone, that is remarkably tight and free from open or discharging seams.

The cofferdam for the Iowa Division embraces 39 acres of the original bed of the river, and as a tribute to the tightness of the bed rock it may be stated that a 4 in. pump, running about four hours a day keeps all the water out of the cofferdam. We are unable to locate any water coming through the cofferdam proper, which has a length of 4,700 ft., and the water that we do find coming into the cofferdam comes in from an old canal bank, finished in 1877, and a part of the present Government lock system.

Right here it might be well to state that navigation in the Des Moines Rapids is now overcome by the use of three locks and a canal about 7½ miles long. The new lock will have a 39 ft. lift and will do away with the necessity not only of the above mentioned narrow canal, but of the three present locks as well, thus affording for the use of the Government a great many facilities in the way of saving in expense of operation and other expenditures, and all of this without any disbursement on the part of the Government.

The new lock which is being built will have a width between walls of 110 ft., and as the lift is 39 ft. we get a somewhat larger lift for the same width than is now being constructed for the Government works at Panama.

The question of the sufficiency of rock foundations has been

one requiring first thought at all times. After excavations have been carried down to a stratum that has the surface appearance of being entirely satisfactory, this surface is then washed with steel brooms and water under pressure, in order that all foreign matter may be located and removed from the surface of the rock. A careful examination is then made of this rock, and if the examination does not reveal any seams or imperfections an exploration drill is then mounted on this surface and a drill hole put down to 35 ft. These drill holes are placed longitudinally on the axis of the dam every 36 ft. After two holes have been thus driven, an air pipe is tightly connected to one hole and 100 lb. pressure of compressed air is applied for the purpose of observing the demonstration from the neighboring open hole. In this way the presence of mud seams is determined, and if no mud is found and there is no difficulty in maintaining the pressure in the first hole the foundations are regarded as satisfactory. The surface of the rock is observed with levels to discover whether it is manifesting any movement under the pressure above indicated, and as the 100 lb. pressure is about four times the water pressure it will be seen that the application is rather severe.

The driving of the exploration holes is noted by a skilled observer; the speed of the drill into its reduced size as it goes down, together with a close observation of the variations in air pressure, are plotted for the purpose of discovering whether the rock is uniformly hard. This method of observing the foundations has been followed throughout the work, and in one case a mud seam 3 in. thick was found about 7 ft. down from the apparently good foundation surface, and this 7 ft. stratum was removed, together with the clay, and the work founded on the lower level. We have put down several holes about 100 ft. deep with well drills, and one well drill near the site was driven 800 ft. for an artesian flow, and while in rock all the way no artesian water was encountered.

Throughout the work new masonry is always let into the solid rock at least 3 ft., and after the work has been finished tests that have been made repeatedly show an air-tight seal of the concrete to the bed rock, and this in cases where a pressure of 100 lb. has been put on to the test hole and maintained for a period of six or seven hours.

The above mentioned methods of testing our foundations are not at all new to this work, and have been a part of the plans of our organization for a good many years.

In constructing the dam the piers and arches are first built, and this part of the construction will extend entirely across the river, with only enough of the bottom of the rollway put in to form a sill for the apparatus that will control the water when

the spillway proper is put in place. A side view of this part of the work is shown in Fig. 2, and will clearly illustrate this situation.

The piers are 6 ft. thick, and average about 55 ft. high, and the arches are 30 in. deep at the crown. Inasmuch as all of the work is too light to be mass concrete, the question of form work had to be given special consideration. The interest charge on the invested capital for this enterprise amounts to more than $3,000 a day, so that all plans had to be framed up to fit this expenditure. In making plans for forms it was immediately found impossible to get carpenters enough to build them in time to complete them for the date specified. The steel forms shown in the views we have had built, and we have nine sets of these forms for our regular

Fig. 2. View of Concrete Piers and Arches.

use. We find the use of steel in this particular class of work to be of surprising value, not only in the saving of time but actually in the saving of first cost of the forms, and this, together with the better class of work we get, confirms the writer's belief that steel in the future will be prominently used for forms wherever duplicate work will permit. These forms cost us in the neighborhood of $65,000, or about 45c per cu. yd. for the number of yards they take care of. This amount is less than the cost of the lumber that would be necessary if lumber were used.

The traveler arrangement for handling the forms is shown in Figs. 3 and 4. The rear traveler takes the forms down and lowers them on a track that runs parallel over the work. From here the forms are moved forward to a position where the fore-

Fig. 3. Traveler for Handling Forms and Concrete.

most traveler can re-erect them into position; this process is repeated as the work goes on, and a complete set of forms, including a pier and arch usually takes about six hours for complete erection. I believe the average time has been 5½ hours for the

Fig. 4. Traveler Handling Concrete.

job so far. These travelers have a capacity of 10 tons on each boom.

The crane on the Illinois shore that handles the buckets of concrete from the end of the bridge out to the incompleted work is shown in Fig. 5. This crane weighs about 200 tons and is operated by compressed air. The out-rigger is 150 ft. and supports three trolleys, each having a capacity of 10,000 lb. at the out-board end. The movement of the concrete buckets along the trolley-ways is controlled by telephone boys in the rigging; these telephone boys have various switches that they can cut into, thus enabling them to stand directly over the place of deposit. One

Fig. 5. Traveler and Crane Handling Concrete.

boy handles one engineman, who wears a telephone; in that way the operation of the buckets becomes safe, rapid, and noiseless. This crane handles about 80 cu. yd. of concrete an hour.

A concrete mixing plant on the Illinois shore is shown in Fig. 6. All concrete on the work is of the same proportion—about 1-3 and 5½. The actual consumption of cement is about 1.15 barrels per cu. yd. of concrete in place.

The mixing is done in steel boxes just over the mixers; the valves filling and emptying these boxes are operated by compressed air, and the general plan of the measuring arrangement is such as to make it practically impossible for an error to be made. An inspector watches the number of sacks being used in each batch. No reinforcement is used anywhere in this work.

On the Iowa Division the complicated form work and the lack of a sufficient amount of duplicate work made it necessary to adopt wooden forms throughout this portion of the undertaking. Forms for the draft tubes have collapsible ribs, and the sheeting and ribs are designed to handle about 10 ft. of concrete

Fig. 6. Concrete Mixing Plant.

per lift. In the design of forms we found that concrete was assumed to assert a hydrostatic pressure of about 70 lb. per sq. ft., and we designed accordingly.

A view of the turbine is shown in Fig. 7. Provision is made in the power house for 30 of these turbines. The normal head is about 32 ft. This is the first attempt to use any such amount of power from one runner, but the one-runner design is manifestly much the better if the elements of power and speed can be made satisfactory. The diameter of this runner is 15 ft. 7 in. It discharges into a draft tube 18 ft. in diameter, and this draft tube gradually expands in area until it is 40 ft. wide at the discharging end and 22 ft. high, with circular sides. The main shaft of the turbine is 25 in. in diameter, and the weight of the rotor, amounting to about 500,000 lb., will be carried on a combination thrust and roller bearing, the idea being that either can be run independently of the other, and the load transferred from one to the other automatically. Recent experience at Niagara, and

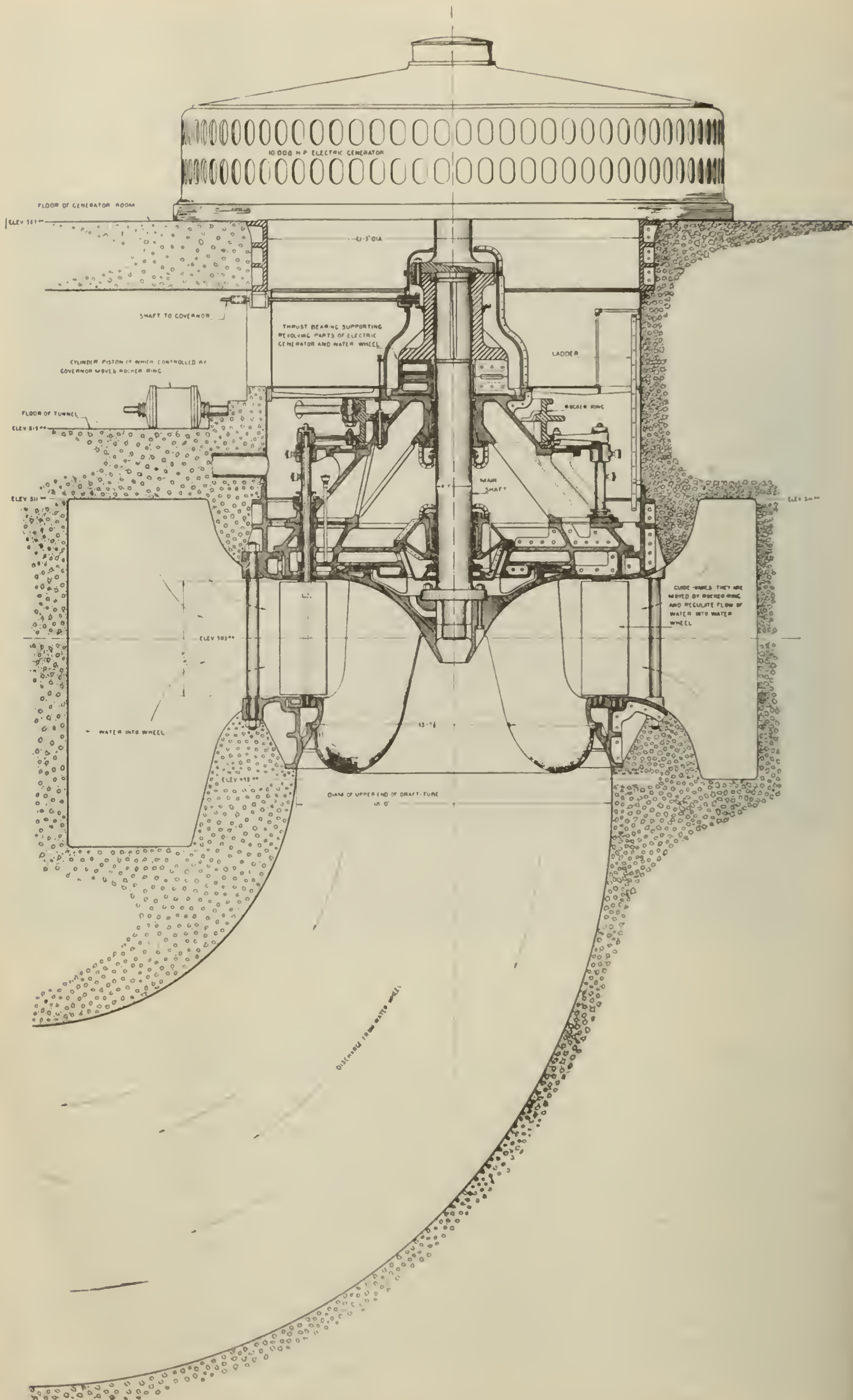

Fig. 7. View of Turbine in Section.

McCall's Ferry, Pennsylvania, would indicate that the roller bearings will be able to handle the entire load without the use of the pressure discs, and the pressure discs will therefore probably be used only for reserve work. The runner itself is cast in one piece, will weigh about 160,000 lb., and will revolve at 57.7 revolutions.

The speed of the runner will be controlled by the manipulation of 20 guide vanes, and the depth of these guide vanes will be 6 ft. 1 in., with the corresponding opening for the periphery of 15 ft. 7 in. referred to above. The operation of the guide vanes will be controlled by two hydraulic cylinders operating under oil pressure through pistons, connecting rods and cranks.

The water will enter the buckets through the guide vanes from a concrete scroll case. The scroll case will be so designed as to always deliver water to the guide vanes at a uniform speed of about 7 ft. per second. This will require a constant reduction in the cross-section of the scroll case, and after the water has passed through the turbine it will be re-discharged into the river through draft tubes also of concrete. These draft tubes will be 18 ft. in diameter at the receiving end and will be 40 ft. wide and 22 ft. high, as above indicated, at the discharging end. The receiving velocity for the draft tubes will be 18 ft. per second and the discharging velocity 4 ft. per second, with a uniform rate of deceleration throughout the length of the tubes.

A plan of the turbine, Fig. 8, shows the governor operating the cylinders. Connection, as you will observe, is very direct and avoids a great deal of lost motion that is a serious element at times in successful regulation.

One of the difficulties encountered in previous plants which we are trying to avoid in this work is loss of head in sharp elbows. You will observe that the radius of the curve for the draft tube axis is very large. Some experiments recently made at Niagara have shown that the loss of head in elbows has previously been very much underestimated, and I believe that too much attention can hardly be given to the question of proper provision for enabling water to change direction without the loss of head.

Whereas water is always theoretically disposed to seek its level and follow a slope, we find in actual practice that the introduction of eddies and other cross-currents is very apt to upset a great many calculations, and you will notice in the design of the scroll case as illustrated by Fig. 9 that the water is divided into four equal parts. One of these four parts is conveyed directly to one-fourth of the wheel. The other three parts are in the scroll that distributes the water around the remaining periphery.

Some recent experiments in Germany in a large open flume

wheel case showed that about one-quarter of the water in the flume, instead of flowing toward the wheel was flowing away

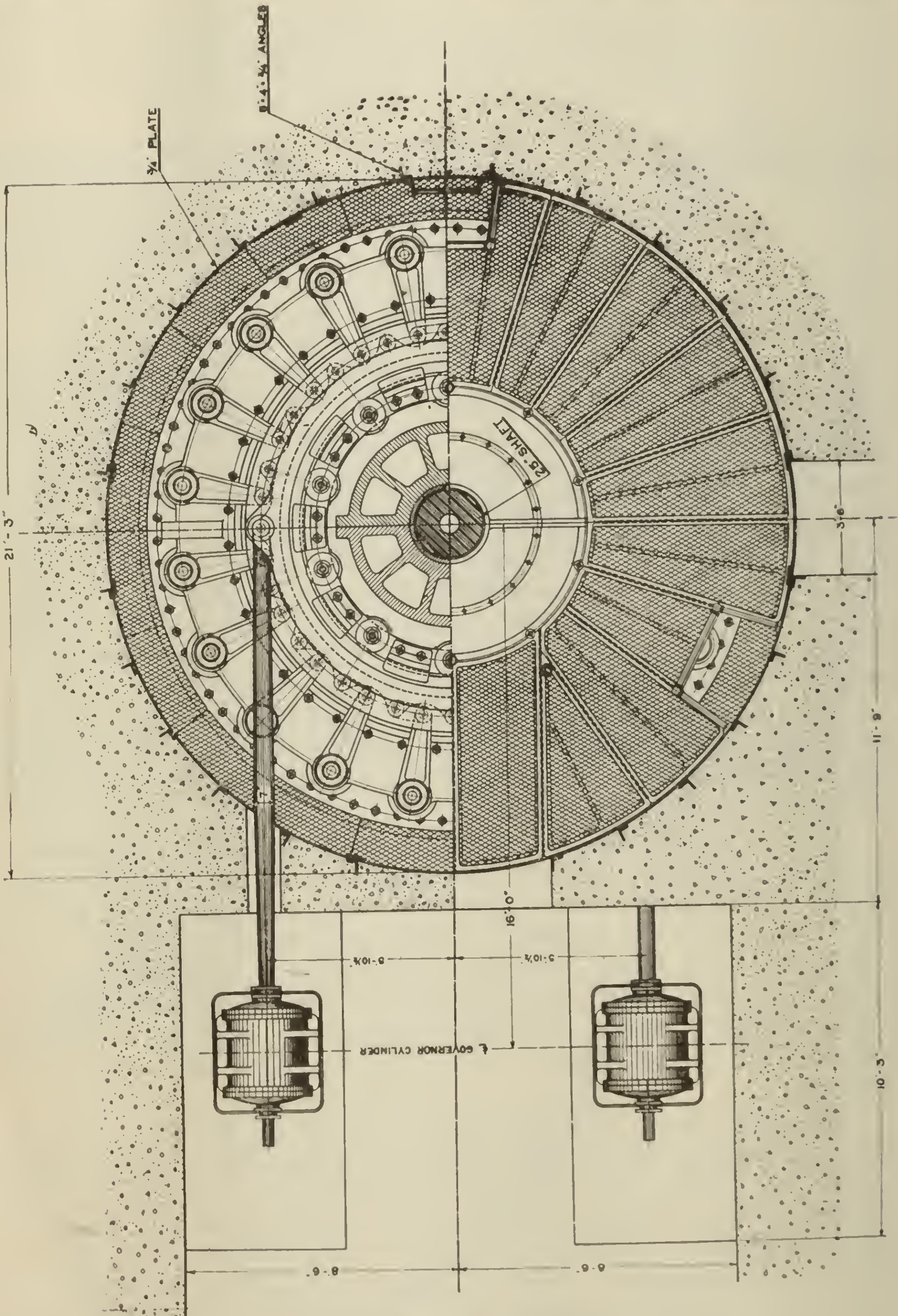

Fig. 8. Plan of Turbine.

from it, resulting in an unbalanced discharge of the wheel, and this unbalanced condition was setting up an abnormal wear in

Fig. 9.

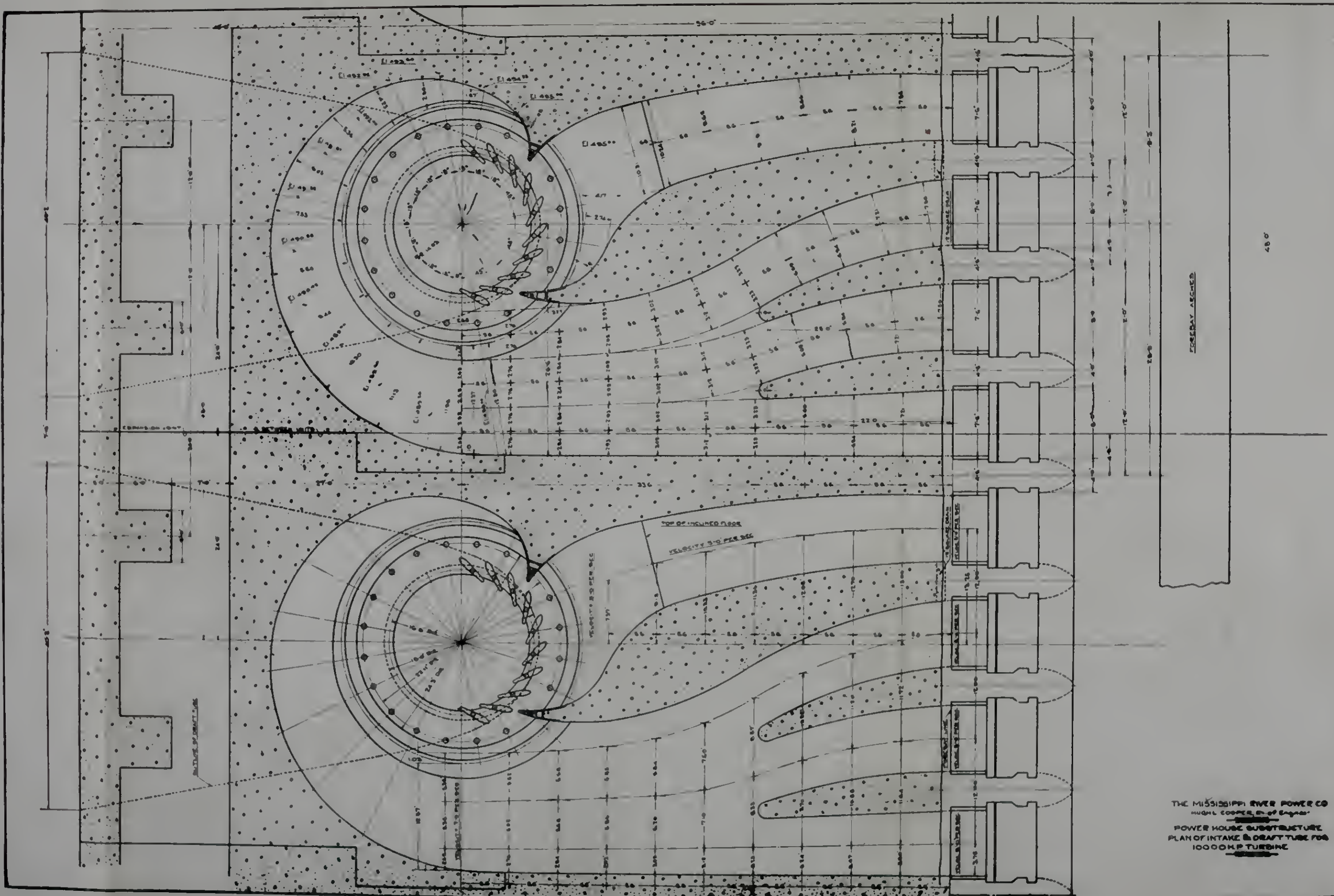
THE MISSISSIPPI RIVER POWER CO
HUGH L. COOPER, Ch. of Engineer
POWER HOUSE SUBSTRUCTURE
PLAN OF INTAKE & DRAFT TUBE FOR
10000 H.P. TURBINE
FOREBAY ARCHES
TOP OF INCLINED FLOOR
VELOCITY 3.0' PER SEC.

Fig. 9

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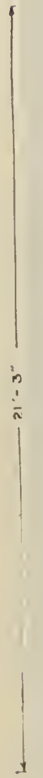

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the main shaft to the extent that the plant had to be shut down and divisions introduced into the flume, the purposes of which were to actually conduct the water to the place it was to be used.

In conclusion, the writer desires to say that Fig. 10 is a view

Fig. 10. End of Draft Tube from Turbine.

of one end of the draft tube forms. Fig. 11 shows work on the lock at the date of this presentation of our work.

We have altogether about 1,500 men employed, many of whom have been on works this organization has constructed elsewhere.

Discussion.

Lyman E. Cooley, M. W. S. E.: This address has been extremely gratifying to me and relates to the best and the most up-to-date example I know of in the way of rapid work in a river where there are great contingencies from floods and other matters. My own connection with the propsition began in 1901, when I was called in by the Keokuk committee to see what could be done in the way of developing the water power of the Keokuk rapids—a fall of some 24 ft. in a distance of 12 miles. The Government had built a canal on the west side of the rapids some eight miles in length, costing $4,500,000, which I think was opened sometime in the seventies. All projects up to that time which had been considered for developing the water power of the

river proceeded on the idea that the canal was not to be disturbed; that a dam must be built at or near the head of the rapids, a race taken down over the eight or ten miles, and the power developed at the end of the race. I made an elaborate investigation on that basis and discovered that it did not work out to my satisfaction financially as well as in a good many other ways.

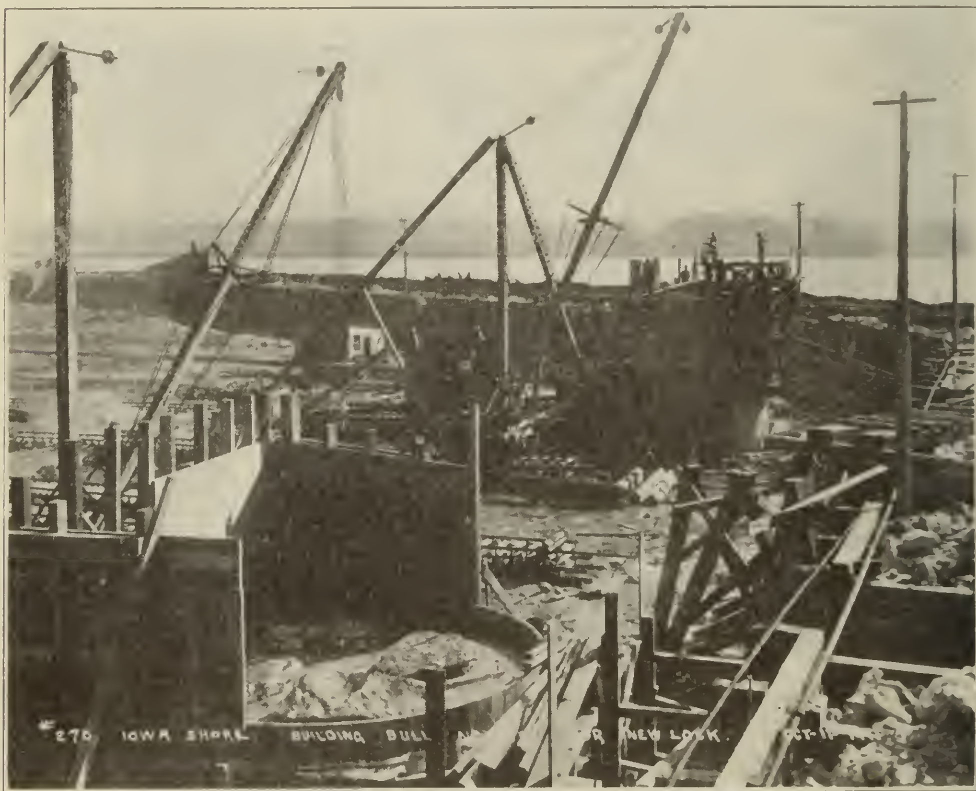

Fig. 11. Work in Progress on Canal Lock.

It then occurred to me to put this dam at the foot of the rapids—a very bold proposition, because it involved the drowning out of this Federal canal, which the Government engineers might not consent to. It would involve the elevation of the C. B. & Q. R. R. tracks for several miles through the gorge at Keokuk, and possibly conflict with steamboat and raft men. As far as I knew it was an entirely new idea to put a dam at the foot of a rapids and not at the head; but from an engineering standpoint, the cost of masonry having decreased so much in the last few years with the use of concrete, it was really the cheapest and best thing to do. That practice has been followed since, in a number of other projects—although it was not made use of previously, as far as I know. So that was the scheme that was decided upon and adopted by the Keokuk committee as a basis

for promoting the enterprise. It is the scheme, substantially, which Mr. Cooper has adopted, with the variation that he proposes to utilize the high water over the dam by means of stop locks, thus getting a better result out of the water. This is a notable feature.

I followed the matter for three or four years, and had many meetings along the river with steamboat and raft men, whose prejudices had to be removed.

There were also conferences with the engineers of the Government—the Board of Engineers. Finally, after all the objections had been overcome, we appeared before a committee at Washington and got our bill through.

Then the committee sought means of financing it. Mr. Cooper made the proper financial combination, and also elaborate surveys and financial plans. My labors never went beyond the broad outline of the scheme.

I gather inferentially that these structures are all gravity structures. In writing the article in the *Americana* on the subject of dams I carefully avoided mentioning any reinforced-concrete proposition. In the light of the experience we have had in some places since, I think I had good reason for this omission. The editor, however, thought that I had left out something and added a paragraph on that subject, much to my disgust and without submitting it to me.

The author mentions that he has determined to make the lock 110 ft. wide. I had some trouble with the Keokuk committee in regard to presenting this matter at Washington, because they thought I was conceding to the Government and to navigation a good deal more than was required. But 110 ft. is getting to be a standard width. We have it on the Ohio River. We have had much discussion in regard to the matter upon the lakes and gulf waterway. As far as the Deep Waterway Associatoin is concerned, they have stopped at that width.

S. T. Smetters, M. W. S. E.: I would ask Mr. Cooper if, when he was placing the forms for the draft tubes and a large amount of concrete beneath them, he ever had any trouble about the forms lifting up.

Mr. Cooper: No. We kept instruments on the forms all the time and, as I remember it, we never raised any particular section over 7 ft. at one deposit. Whether we could have gone any higher than that I do not know, but we did go 7 ft. deep at the bottom without pressure created by that depth lifting the forms. This was because they were so heavy.

John Ericson, M. W. S. E.: I would ask Mr. Cooper if, in handling such large quantities of concrete under such conditions as are described, he can tell us how much that concrete cost.

Mr. Cooper: Yes, approximately. The question as to the

cost of concrete, of course, takes in so many different elements it is difficult to give at this time anything definite except to say that our operating cost has been about $3.50; but that operating cost includes only the following items: The cost of the cement, quarrying the rock, breaking the stone, mixing the concrete and placing the same, erection of the forms, superintendence of the same, and the power. This cost has nothing to do with the overhead charges of engineering, first cost of forms, first cost of apparatus, cost of cofferdams, and all the other various overhead charges. My opinion is that the concrete will cost, when we get through with it, about $7.50 per cu. yd. right straight through. This will probably sound like a strange statement, because ordinarily any engineer in making an estimate, when taking the operating cost into consideration would hardly increase this 150% for the total cost. With us, however, the conditions are very unusual, as on account of the very large interest charge we have to face we have had to install an extra amount of new, large, and special machinery, and our tools and equipment charge against a yard of concrete is something over $1.50.

Oscar E. Strehlow, M. W. S. E.: I would ask Mr. Cooper if in passing the high water flow, the course of the spillway is carried to final height or just the surface of the ground on the Illinois side.

Mr. Cooper: The spillway is left down low all the way across until the piers and arch work are completed. The only concrete we place in the spillway is enough in the bottom for a sill, which sill is to form a part of the portable cofferdam that unwaters these sections when they are to be raised. After the first crossing is made and a suitable stage of water is available, and when the power-house construction is sufficiently advanced, the intermediate openings will be raised in about 5 ft. courses, wherein each course will be carried clear across the river before anything further is done.

A Member: What is the rating of the generators?

Mr. Cooper: The rating of the generators will be 7,500 k. w. They have an overload capacity of about 20%.

TYPES OF SHALLOW FLOORS FOR RAILROAD BRIDGES

O. F. DALSTROM, M. W. S. E.

Presented before the Bridge and Structural Section December 13, 1911.

THE SHALLOW TROUGH FLOOR BRIDGE.

In railroad bridges of the through type, designed for crossings where local conditions do not govern the depth of the floor system, that depth is determined by sections that give the greatest economy of material consistent with simplicity of construction and facility of erection.

The floor beam usually determines the depth of floor in designs of open floor through bridges, whether truss or plate girder type. The term "depth of floor" will be used throughout this discussion to indicate the distance from base of rail to lowest steel of span. If considerations governing the design of the trusses produce panels of considerable length, the stringers, instead of the floor beams, may determine the depth of floor. A single-track truss span of 350 to 400 ft., with trusses 18 ft. 6 in. or 19 ft. centers, may have panels over 30 ft. in length. In such a design the economical depth of the stringer would be about the same as that of the floor beam. In common practice the floor beam would still be made deeper than the stringer to obtain simple details of connection between these members.

But conditions of grade and requirements of clearance below the bridge may make it necessary, in a measure, to disregard economy of material and simplicity of construction and erection to obtain designs that will meet all the requirements in special cases. Difficult conditions of grade and under clearance, necessitating extreme shallowness of floor, are frequently encountered in crossings over streets and over other railroads; and the type best adapted to any particular crossing must be determined by a careful study of the local conditions.

A crossing over another railroad usually means grades carried above the normal grade of the line, with a through bridge over the railroad at the apex of the grades. If the approach grades are long and heavy, the slightest reduction in the depth of the floor of the bridge means an appreciable reduction in the cost of the approaches. And—what may be of greater significance than the reduction of the cost of bridge and approaches—it means the reduction of grades that would be costly and otherwise objectionable, or practically impossible, from the standpoint of operation, where local conditions determine limit of running out of the grade.

March, 1912

The files of the bridge department of the C. & N. W. Ry. Co. contain the plans of a large number of bridges that have been designed to meet extreme conditions of clearance, grade, and curvature. A few of these designs have been selected, with special reference to shallowness of floor, as typical.

Plate IX shows the floor details in the design of a double track through truss bridge of 170 ft. span, in which the depth of floor is 1 ft. 11 in. This bridge is designed for Cooper's Class E-50 locomotive; or a concentration of 60,000-lb. on each of two axles spaced 6 ft. 0 in. center to center. The specifications for loading, unit stresses, etc., are given in the General Notes on Plate X.

The floor is of trough construction, the troughs being placed perpendicular to the axis of the bridge. Each trough carries a tie under each track, as shown in Plate IX transverse section through troughs and floor beams; the tie is supported at four points on horizontal angles riveted to the tops of diaphragms extending between the webs of the troughs. In every alternate trough, except those adjacent to the floor beam, special diaphragms are provided near the ends of the ties. To these diaphragms the ties are anchored by bolts through the horizontal angles at the tops of the diaphragms, which are so located in the troughs that the bolts will be about 4 in.—a convenient working distance—inside the guard rail. The horizontal legs of the angles at the tops are turned toward the ends of the ties to make the bolts accessible after the ties are put in place. The tie bolt diaphragms are omitted in the troughs adjacent to the floor beams, as they would interfere with the driving of the field rivets at the ends of these troughs.

The troughs (Half-Section B-B), are carried by longitudinal girders which are parallel to the trusses, and placed at a sufficient distance from the lower chord to permit ready inspection of chord and girder. The longitudinal girders are carried by the floor beams (Half-Section A-A) which are designed to receive the entire panel load and transmit it to the truss.

The troughs are designed to carry a concentration of 60,000-lb. on each track, each concentration distributed over two ties. This gives a load of 30,000-lb. on each of the two ties carried by the trough, or 60,000-lb. carried by the trough.

The floor beam is designed to carry the load from the intermediate troughs, concentrated at the bearings of the longitudinal girders, 2 ft. 1 in. from the center lines of the trusses; and, in addition, to carry its part of the load on the ties in the adjacent troughs.

The heavy load carried by the floor beam, together with its greater length, requires in this member a section considerably heavier than that of the troughs. The depth back to back of angles is made the same in floor beam and troughs, but the addi-

tion of flange material required to give the necessary section modulus in the floor beam, makes the extreme depth of this member somewhat greater than that of the trough sections. This extreme depth of floor beam determines the depth of floor for this type of bridge. By flattening the rivets under the rail and allowing a clearance of 1 in. from the base of rail to the tops of the flattened rivet heads, a satisfactory section is worked out with a depth of floor of 1 ft. 11 in.

It will be noted that the material in the floor beam and trough sections is not disposed symmetrically with reference to a horizontal line at the middle of the section. In order to obtain the most effective distribution of material, the neutral axis is maintained at the middle of the section. The metal is increased on the tension (lower) side to make up for the reduction of section by rivet holes, no allowance for reduction of section by rivet holes being necessary on the compression (upper) side of the section.

The depth of the longitudinal girders is made considerably greater than economic considerations require for the section. This is done to obtain a good detail at the end bearing and at the connection to the floor beam.

The top flange of this girder is unsymmetrical, being composed of a plate and angle, the angle placed with its face against the web, the horizontal leg projecting over the top of the web and outward from the track. This detail of the top flange is to gain an additional horizontal clearance, as at this point the structure approaches nearer to the clearance diagram than at any other place except at the end post, where the edge of the cover plate is coincident with the extreme vertical line of the clearance diagram. An advantage in erection is also obtained by this detail of top flange section, as it permits setting the trough sections in place on the bottom flanges of the girders, with only a very slight displacement of the girders from their permanent position.

To further facilitate erection of the troughs, the stiffeners are omitted from the inner side of the longitudinal girder. The end connection angles of the troughs, which are field riveted to the web of the girders, are placed high enough so that the tie bolt diaphragms near the ends of the troughs will not interfere with the driving of the field rivets at the ends of the troughs in which the tie bolt diaphragms occur.

The troughs are drained through 1 in. gas pipes fitted into holes in their bottoms and projecting slightly below the trough to form a drip. (Typical section showing floor and drainage). This projection of the drain pipes must not extend below the line of low steel determined by the rivet heads on the under side of the extreme cover plate of the bottom of the floor beam. The upper ends of the drain pipes are threaded into washers to hold them in place.

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The lower part of the troughs is filled with asphalt mastic, the surface sloping toward the drain pipes and flashed over the washers at the upper ends of the pipes. A layer of broken stone covered with gravel is spread over the mastic for a protection.

The deflection of this floor under a maximum load is considerably greater than that of floors designed for depths determined by economical sections. Under maximum load the theoretical deflection at the center of the floor beam is 0.65 in.

The erection of truss bridges of the open trough floor type requires a special order of work in riveting owing to the longitudinal girders being located so close to the trusses.

After the girders have been placed in position, no riveting can be done on the inside of the lower chord opposite the girder. On this account all riveting in the trusses below the level of the tops of the girders must be done before the girders go into place, which means that all lower chord splices, floor beam connections to trusses, and web member connections to gusset plates, up to the level of the tops of the girders, must be riveted before placing girders and trough sections. There is no interference from the girder in driving the rivets on the outside of the truss, but these rivets, up to the level of the tops of the girders, should be driven at the same time that the riveting on the opposite side of the truss is done.

Plate XI is the plan of the falsework used in erecting a 120 ft. truss bridge of this type, on the C. & N. W. Ry. near Denison, Iowa. This design of falsework provides for the erection of the bridge without interruption to the movement of trains. The order of procedure is given in full on the plan.

The bridge at which this falsework was used is located on the main line of the C. & N. W. Ry. between Chicago and Omaha,—a line which carries an enormous volume of traffic. Trains were operated under slow orders over the bridge during erection, but there was no interruption to traffic, and no delays except such as are incident to the erection of a large bridge of any type on a busy line.

In the development of this type of shallow floor for double track bridges, the first efforts were directed toward obtaining an open floor design, with stringers beneath the track, transmitting the load directly to the floor beam. The excessive bending moment in the floor beam, resulting from this arrangement, made it impracticable to design a floor beam that would come within the required limits of depth of floor.

Following this, a trough floor type was designed, differing from the one shown on Plate IX in that it had no longitudinal girders to carry the troughs. Instead, the troughs were extended to the trusses and connected to the bottom chord in the same manner that the floor beam on Plate IX is connected to the chord

at the panel point. The bottom chord was designed to act as a girder, to carry the panel loads to the panel points.

This design brought the depth of floor within the required limits, but made the troughs excessively heavy. The bottom chord was necessarily made deep and heavy, since it had to act as a beam for the floor troughs at the same time that it was doing duty as a tension member in the truss.

The next step was the introduction of the longitudinal girder. This was placed as close to the track as the clearance diagram would permit, to reduce as far as possible the bending moment, and thereby the sections, of the floor troughs. The introduction of the longitudinal girder changed the bottom chord from a combined beam and tension member to a simple tension member, and eliminated from it the objectionable secondary stresses produced by the vertical loads applied at the trough connections.

Below are given a few figures for the comparison of a 170 ft. double-track span of the above type, and a double-track span of the same length, with the usual open floor construction, in which the floor beam and stringer sections are determined by the economical depth.

	Shallow Trough Floor Type.	Deep Floor Type.
Depth of floor	1 ft. 11 in.	4 ft. 9 in.
Weight of floor system per lineal foot of bridge................	5,000-lb.	1,700-lb.
Weight of trusses and bracing, per lineal foot of bridge..........	3,400-lb.	3,250-lb.
Weight of 170-ft. span, complete...	1,496,000-lb.	900,000-lb.
Total cost of span, f. o. b. cars at bridge company's plant, at $0.025 per lb.	$37,400.00	$22,500.00

Difference, $14,900.00 = 66.2% of deep floor type.

As the depth of floor is increased, the weight diminishes rapidly. At 2 ft. 4¼ in. depth, the weight is 4,100-lb. per lineal foot of bridge. This is the weight of the floor in the bridge at Denison, Iowa. Further increase of depth would show a corresponding decrease in weight until the minimum thickness of material in sections is reached.

Unit prices in bids submitted by bridge companies for the fabrication of material for the shallow trough floor type, have been found to run about the same as those submitted at the same time for open floor truss bridges. On this basis, a comparison of the two types of the span selected show that the shallow floor

type would cost, f. o. b. cars at bridge company's plant, about 66% more than the deep floor type.

The cost per ton for erecting would be about the same for both types. The number of field rivets per ton is somewhat less in the shallow floor type than in the other type; but an allowance, for which no figures are at present available, must be made for the order of procedure in riveting, which requires that part of the riveting be done before all the material in the bridge is assembled, and for the additional falsework and blocking that is necessary under the floor system to provide for the uninterrupted movement of trains.

The comparison of costs of the two types erected would show about the same relation as that of the costs of fabrication.

The range of application of floors of this type in double-track truss bridges would cover depths of floor of about 3 ft. and under, if the panel lengths do not exceed 15 ft. With a depth of floor over 3 ft. an open floor bridge is practicable and would be more economical.

For double-track through girder bridges, where panel lengths can be varied as desired, the application would be limited to about 2 ft. 6 in. depth of floor.

THE SHALLOW OPEN FLOOR BRIDGE.

A design of open floor, double-track bridge, with 1 ft. 6 in. depth of floor is shown on Plate XII. This is the plan of a bridge erected near Mapleton, Wis., on the new line of the M. S. & N. W. Ry. The design shown is for a double-track bridge, but the type is applicable to crossings with any number of tracks at the standard distance of 13 ft. centers. The limitation of this type of bridge is in the direction of span lengths, being suitable only for spans of less than 40 ft.

The relation of the clearance diagram to the girders shows that in the longer spans, the girders and not the floor beams or stringers determine the depth of floor. The section of the middle girder, which carries load from both tracks, is exceptionally heavy, while that of the floor beams have no shapes over ⅝ in. thick. In shorter spans, 20 to 25 ft., it would be possible to make a shallower girder and reduce the depth of the floor beam so that the depth of the floor would be about 1 ft. 3 in. At that depth the stringer would be so shallow that any further attempt to reduce the depth of floor would result in stringers so shallow and short, and floor beams so close together, that the floor would consist of floor beams connected by diaphragms acting as stringers. It would be approximating the type described above under the name of shallow trough floor bridges.

In spans of 15 ft. or less, the girders can be brought under the third offset of the clearance diagram, making the floor beams shorter and lighter. At this point the depth of floor would prob-

ably be determined by the stringer, and the floor beam would be designed in accordance with that depth.

SHALLOW OPEN FLOOR SUBWAY, WITH SIDEWALK PROTECTION.

Plate XIII is the general plan and typical details for a subway bridge designed to meet special conditions as to (a) skew, (b) depth of floor, and (c) protection over sidewalk. It is essentially an open floor bridge, with special arrangements for sidewalk protection. As the conditions of approval for this crossing did not require protection over the roadway, this part was made of the open floor type, similar to that on Plate XII, but without the intermediate girder. The span length here is too great to permit the introduction of the intermediate girder without spreading the tracks; and the 2 ft. depth of floor admits floor beams of sufficient depth to carry both tracks. In addition, this type of floor was found to give simple details of floor at the cross girders over the curb, where the floor changes to the deck plate girder type.

The sidewalk spans are designed with special reference to protection for sidewalks. To give adequate protection from cinders, dirt, and dripping oil and water, it was necessary to make these spans waterproof. This was done by making them ordinary deck plate girders with buckle plates on the bottom flanges to carry the waterproofing, and extending out beyond the cross girders to carry the drainage to the gutters. The waterproofing consists of a layer of asphalt mastic, sloping towards the curbs.

As the buckle plates carry no weight except their own and that of the waterproofing, the lightest obtainable plates are used, and the buckle is turned up to avoid encroaching on the vertical clearance over the sidewalk, and also to avoid lowering the cross girders, or providing special detail of plate to carry the drainage past the cross girders.

Special bridge seat castings are placed under one pair of the sidewalk girders of each track, as near the coping as allowable to prevent excessive deflection under one rail. The continuity of the girders is interrupted at this bearing by making a short, independent span extending from this bearing to the one at the backwall.

THE RAIL GIRDER.

Plate XIV is the plan of a girder designed to carry a track over a 4 ft. 6 in. clear span in places where there is not sufficient space for stringers and ties below the rail. Conditions requiring such designs are not uncommon in railroad yards and in city streets, where pipes and conduits are laid close to the grade of the track.

This design consists essentially of an independent girder for each rail, built up of Z shapes and bars. Section E-E is a transverse section of the girder, showing the rail held in place by cast iron clips bolted to the webs of the Z's. The depth of floor is 3

in., using the term in the same sense as in the discussion of the previous types.

In the design of the girder it is assumed that both rail and girder will be effective in resisting the bending under load. They will act as separate units, however. Both rail and girder will be deflected the same amount, but as they are of different sections, the stresses in the extreme fibers will not be the same, but will be proportionate to the distance of the extreme fiber from the neutral axis in each case. This distance in the girder is 3 in. In the rail shown it is 2⅞ in., or 0.96 of that of the girder.

The section modulus of the girder given below, Section E-E, is the actual section modulus of the net section of the girder. The "effective" section modulus given for the rail is 0.96 of the actual section modulus of the rail. The sum is the effective section modulus of girder and rail acting as separate units, and deflected the same amount.

Assuming a span of 5 ft. 0 in. center to center of bearing under maximum load of 30,000-lb. at the center of span, the bending moment at center of span is 900,000 inch pounds, counting dead load and impact equal to live load. This gives a maximum fiber stress of about 18,000-lb. in the girder.

Section E-E shows a 90-lb. A. S. C. E. rail section, on the girder. Any type of rail can be used with the girder by varying the details of the cast iron clips to conform to the section of the rail to be used.

The space in the girder on each side of the rail is filled with asphalt mastic, to protect the steel and provide a run off for drainage.

The section marked "special type" is a modification of this girder section, which permits the top of the rail to come down almost level with the top of the girder. It is designed especially for city streets, where it is desired to have the top of the rail level with the pavement.

The weight of this special section is about the same as that of the standard section, but on account of the greater depth it has a considerably larger section modulus, 55.4, as compared with 39.0 of the standard section.

The objection to adopting this stiffer girder as the standard type is that the rail and the top of the girder form a small groove for the flanges of the wheels to run in. This groove requires attention to keep it from getting full of stones, sticks, and street refuse; there is also a possible danger of derailment from the projecting corner of the girder, unless a perfectly true gauge of the track is maintained in anchoring the girders. The corners of the girders are planed off on the gauge side, to reduce this danger to a minimum. The standard type of rail girder is free from these objectionable features.

In this drawing is also shown the detail of the reinforced

concrete slab designed to close the space between the rails, and on each side of the track. Blocks of wood are inserted in pockets adjacent to the rails and opposite to the rail clips to facilitate the removal of the rail by making the rail clip bolts accessible. The interstices between the block and concrete are filled with sand. Holes through the concrete below the blocks provide drainage for the pockets.

The weight of a pair of girders of the section shown in Section E-E is about 1,500-lb. The weight of a pair of the special section is practically the same as that of the standard section.

Plate XV is the design of a girder to carry a track over a 6 ft. clear span. This is a section built up of plates and angles, and differs from the girders on Plate XIV only in the arrangement of material to obtain the increased section necessary for a clear span of 6 ft. The depth of floor is 5½ in.

The weight of a pair of girders of this type is about 2,500-lb.

The concrete slabs do not differ in any essential details from those for the other types of rail girders.

In the construction of the concrete slabs between the rails, care must be exercised to prevent the reinforcement steel from forming an electrical connection between the rails. A case is on record in which the slab was constructed in one piece, instead of in halves, as shown. The reinforcement steel was laid in contact with both girders, establishing a complete electrical circuit between the girders and the rails. The effect of this on the signals in that block was, of course, the same as that of a train in the block. By constructing the slab in halves, as shown in the drawing, and interrupting the continuity of the reinforcement at the center of the track, there should be no difficulty in keeping the girders insulated.

Discussion.

John Brunner, M. W. S. E. (Chairman): The paper which has been presented to us tonight deals with some of the most difficult problems, perhaps, which the bridge designer has to solve, namely, satisfactory shallow bridge floors. I believe that the track elevations here in Chicago have probably developed and brought out a greater number of different designs of shallow bridge floors than all other bridge designs taken together. As many of you gentlemen have taken part in making these designs for shallow floors, I hope that we shall have a good discussion of this subject.

I. F. Stern, M. W. S. E.: The paper shows, it seems to me, what can be done if it has to be done. A problem was presented to the bridge department of the C. & N. W. Ry. Co. as to how much the depth of the floor of bridges could be cut down. It was variously estimated that if the floor could be cut down between one and two feet, a saving of $10,000 to $25,000 could be

effected. After a study of the problem, a type was evolved as shown by Mr. Dalstrom, with a 2 ft. depth of floor. The peculiar feature about this whole thing was that after having developed a 2 ft. floor, which was about 2 ft. shallower than had been used before in the history of the road, every locating engineer when putting a grade on for a new line found he absolutely had to have a 2 ft. floor. After the first designs were out, the resident and locating engineers found that they could not possibly use a floor of more than 2 ft. in depth on all future work, so the bridge department had to provide it.

The same thing applies to the little rail girder that the author mentions near the end of his paper, where the distance from the base of rail to low iron is about 2 in. That type was developed to suit some particular necessary situation, but we found that in the next season there were recommendations for 100 to 200 such places where they felt they could not get along without it, though in some cases we could give them 2 and even 3 ft. from the base of rail to low iron, without affecting anything. Of course, where possible, we put in a solid floor, a concrete culvert with ballast on top, which gave a better riding rail.

Another noticeable thing brought forth in this paper is that interesting game of dodging the clearance line. You will notice that the clearance line that is given there is stepped off, and as a result we have been able to do things with it, such as coming inside of some of the projections, without interfering with the clearance line. That could not possibly be done in the ordinary standard clearance diagram, where there are diagonal lines connecting the horizontal lines at the top of the rail to the side clearance. It is a question whether other designers want to do that, but this clearance diagram was developed from actual conditions. In some cases (the American Railway Association, especially where they have electrification to consider), a similar diagram has been used, so I think it is quite consistent. And one really can do things with it that he cannot do with the other.

As Mr. Dalstrom has stated, the development of this type of floor is rather interesting. The C. & N. W. Ry. Co. tried a great many schemes to cut down the level of the grade of the track, its height being in some measure, of course, necessitated by the fact that 22 ft. 6 in. clearance over the road that we crossed had to be provided. In one instance we spaced the floor beams so that they came in between the two parts of the clearance diagram over the two tracks. If we take the clearance diagrams for each track, we have a little triangular space between them, and the first design that was submitted contemplated the floor beam going down in this space, so that the limit was set by the depth from the base of the rail to the bottom of the stringer. This, however, is not a new device, and the most notable example that I know is on Clark street, in Chicago,

where the St. Charles Air Line crosses the street-car tracks. On account of switches on the bridge the double track St. Charles Air Line could not have a center girder such as is used on the other crossings, and after studying the situation—it happened about twelve or thirteen years ago—a hanging girder was developed there. This hanging girder has been hit once or twice by the street cars, but it is still doing duty and is a safe structure.

I think Mr. Dalstrom has called attention very clearly to the general idea in the design where all the possible elements that tend to make shallowness in depth of floor have been taken advantage of.

We have the trough floor beam at the panel points. The loads coming on this are so close to the points of support, the centers of trusses, that a great bending moment is not developed on the floor beam. We take care of shear, but the bending moment is cut down a good deal more than was deemed at first possible. In the ordinary floor where we have stringers, some of them coming close to the center of the floor beam, the bending moment is three or four times as much as in this type. The idea of taking care of the bending moment by longitudinal girders which can be made of great depth seemed to commend itself to the designers and was properly worked out. That, of course, also gave the additional advantage of shortening the length of the trough floor beams or the intermediate troughs so that there was not as great a bending moment in them. We had to go to the trough floor, which has been objected to by a great many bridge companies. It has always been said that it costs more to build this type of floor than the ordinary type. It has been objected to on ordinary track-elevation work where the trough floor is used to a considerable extent. It seems, however, when the bids come in from a bridge company that the unit price for trough floor is just about the same as for the ordinary floor, so that I do not think that argument would hold very well. I do not know that this floor should be used if it can be avoided. I do not think that it is the best type of floor, if we can avoid it. The deflection in the floor beam is 2/3 in., and that is a good deal for that type of trough. So there are many objections to the floor. However, it was the case of a problem coming up where, with a supported grade line, such as had to be used to get the required clearance over the railroad that was crossed, it was absolutely essential to cut down the depth of the floor to the absolute minimum, and I think that this has been done.

Josiah Gibson, M. W. S. E.: I would like to ask if these floors are used only for double track. The paper shows double-track designs in all cases. Would it be possible to use such a floor

for single track or would it be too heavy? Would an I-beam for a single track be a better proposition?

Mr. Dalstrom: The design that was selected as a type is the double-track span that has been developed as a standard. This type of floor can be applied to single-track as well as to double-track bridges, and in a single-track bridge the depth of floor can be made even less than that shown in the typical double-track design.

The bridge at Denison, Iowa, which has been referred to in the paper, is a three-track bridge, carrying two main tracks and one side track, the intermediate truss being placed between the side track and the main tracks. In this bridge the double-track floor under the two main tracks is 2 ft. 4¼ in. deep, while the single-track floor under the side track is only 1 ft. 6¼ in. deep.

In single-track bridges there is less difficulty in designing open floors of sufficient shallowness, than in double-track bridges, and wherever an open floor design can be applied, it should be adopted in preference to the trough floor.

F. G. Vent, M. W. S. E.: Referring to the detail drawing of the 4 ft. 6 in. span, it will be noted that the shop orders are to grind both ends of the girders as indicated, on account of the danger of the wheel flanges hitting the Z-bar girder. It would be well if they were ground back to a light taper, for a foot or more. The note would indicate that they were to be ground to perhaps a 2-in. radius, for the purpose of guiding the wheel flanges of a passing train into the narrow space of 2 in.—a space about the distance of the ordinary guard rail from the main rail. The ordinary guard rail is tapered off so that there is no chance of a wheel flange ever hitting anything very suddenly. I think on this type of floor it would be well, even if the girder had to be made 7 ft. long, to have a light taper a foot long at each approach.

My criticism is made, not that I would necessarily fear a derailment at a bridge of this kind, but because of the danger of cracking flanges, which might engage anything as close as a guard rail, by allowing them to bump into place on a rounded corner when the bump can be eased off just as well as not, and a resulting derailment might occur at a much worse place than at the bridge.

Mr. Dalstrom: On the special type of rail girder—the type in which the top of the rail is practically on a level with the top of the girder—the corner of the girder is beveled off. At the end of the girder this cut amounts to 1¼ in. horizontal, and about 2½ in. vertical, as shown in the section, and this bend extends back along the girder to a point 7½ in. from the end, where it runs out.

On the standard type of rail girder, where the top of rail is high enough to bring the flange of the wheel entirely above the

top of the girder, there can be no danger of the flange of the wheel striking the corner of the girder; and on this type the corner of the girder is ground off only enough to give a neat and finished appearance.

J. C. Sanderson, M. W. S. E.: The author's valuable paper might have been made still more valuable, for some of us at least, had he given his reasons for adopting the type of floor used on the 170 ft. double-track span.

It might be inferred from the paper that local conditions made it undesirable to raise the grade. A three-truss design might, however, have been adopted, making the floor comparatively simple and have effected a considerable saving of metal. The truss between tracks is objectionable, but to the writer's mind is less objectionable than the floor adopted.

The floor as designed presents a serious problem in maintenance. The ballast and poor circulation of air on account of the ties and diaphragms will keep the metal moist for a considerable part of the time. This metal that should receive frequent attention is difficult to get at for either painting or inspection.

For this particular place it is hard to see why a trough floor, which is one of the most uneconomical, should have been adopted instead of an open I-beam floor. With the same arrangement of longitudinal girders and diaphragms—except that one diaphragm under each rail be made to carry moment, thus making the live load practically uniform—the load could be carried by 20 in. I-beams 18 in. centers. The floor beams would be practically as in the author's design. If, however, the longitudinal girders were put at the center of the chord, using wide gauge connection angles so the girders would not take tension, the load could be carried by 24 in. I-beams 18 in. centers, with the details for the ties and distributing girders as for the 20 in. I-beams. This design raises the grade about 3 in., but avoids the heavy floor beams and their cumbersome details. Either one of these I-beam floors would greatly reduce the metal required, do away with ballast and waterproofing, and reduce the cost of erection.

PROTECTION OF HIGH TENSION POWER CIRCUITS AND APPARATUS

JAMES LYMAN, M. W. S. E.

Presented before a Joint Meeting of the Electrical Section W. S. E. and Chicago Section A. I. E. E., December 27, 1911.

Great economies are effected in the manufacture of electric power by the use of large generator units operating under a high load factor. This has led electric light companies to go after all kinds of industrial power, to centralize the manufacture of current in one or more large power houses, and to extend their distribu-

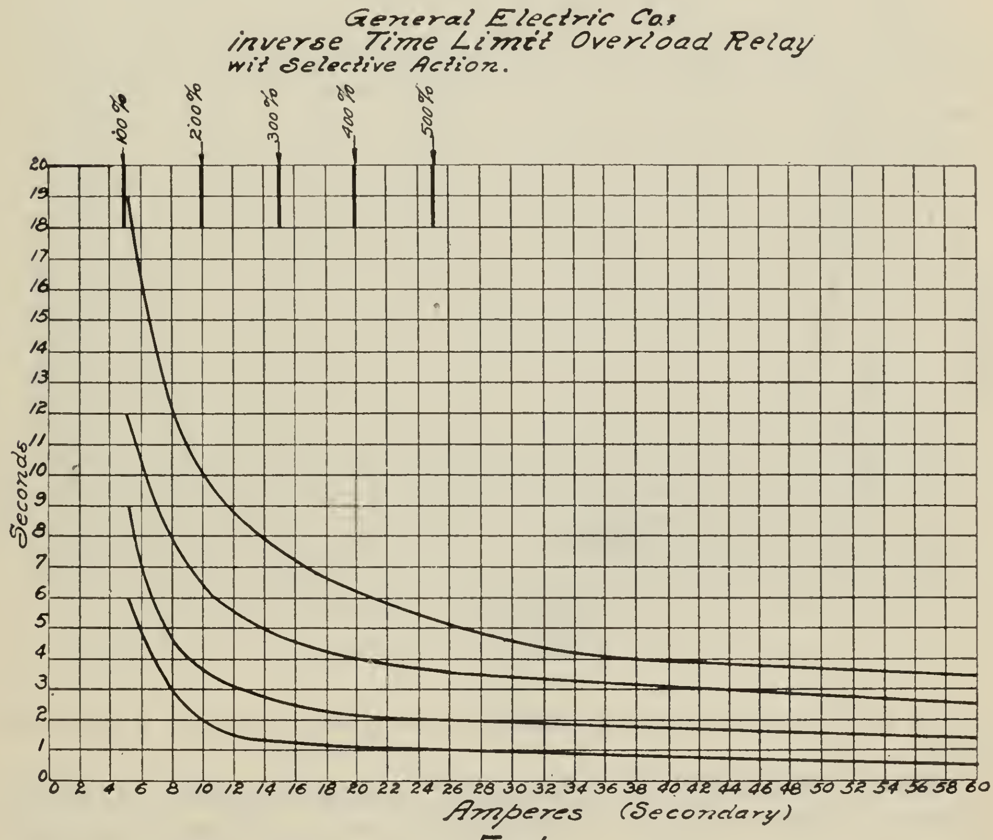


FIG. 1

Each curve is from one setting of the relay.

tion systems to serve the whole community. Absolute continuity of service is required, and with the constant growth of the business and the extension of the lines the problem of maintaining this continuity of service is one of the most serious problems confronting electrical engineers, for, however well the overhead and under-

ground lines may be insulated and installed, faults will occasionally develop, and the larger and more extended the system the oftener they may occur. Provision should, therefore, be made for supplying electric power to all important centers of distribution by more than one circuit, operating these circuits in multiple and protecting each by automatically controlled switches that will cut out any circuit in which a fault may develop.

It is with reference to this protection of heavy A. C. power

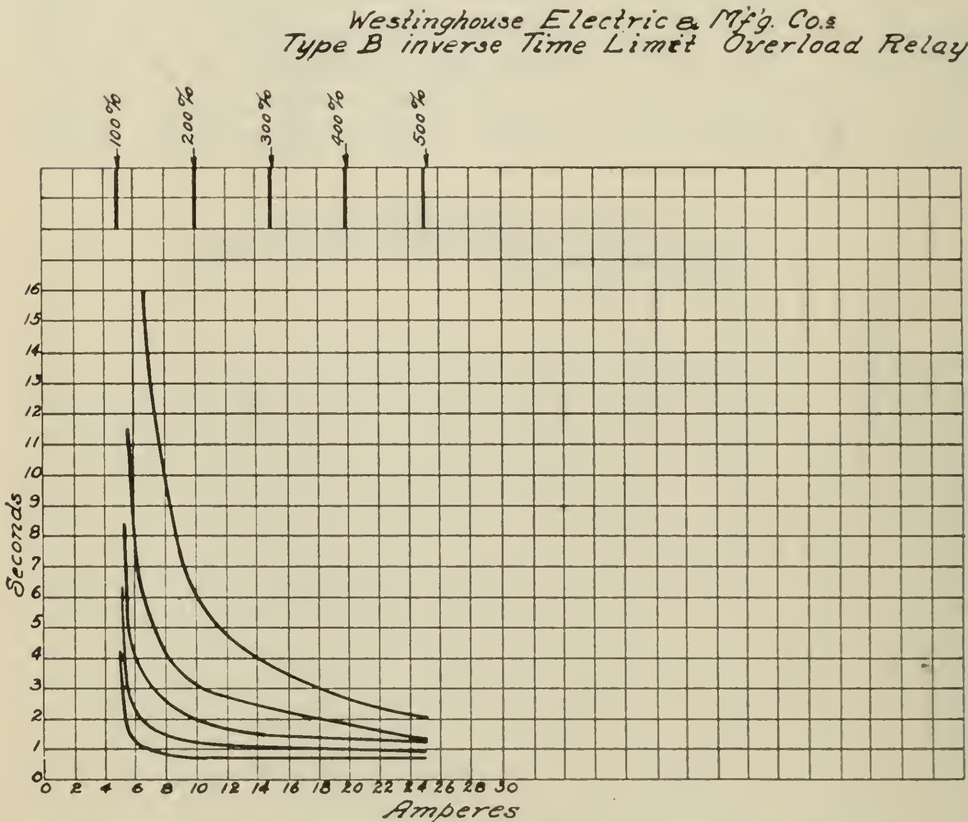


FIG. 2

feeders and power house apparatus that this paper has been prepared.

Most of the large city lighting and railway companies generate at 6,600 to 13,200 volts, 25 or 60 cycle current, and transmit at generated voltage to sub-stations. Frequently the distances to some of the sub-stations are too great for the generator voltage, and banks of transformers are provided to obtain an economical transmission potential. In extended systems it is frequently necessary to supply several sub-stations in series from one or two feeders or transmission lines. At the sub-stations the current is transformed to direct current or alternating current suitable for the distribution system

The present general practice in this country provides for automatically opening the oil switches or circuit breakers at the power house end of all feeders, not instantly but after a sufficient interval of time has elapsed to permit any momentary surge or overload currents to pass away. The relays performing this function are usually of the inverse-time-limit overload type, having characteristic curves as shown in Figs. 1 and 2,—Fig. 1 for the solenoid type as manufactured by the General Electric Company, and Fig. 2 for the watt-meter type as manufactured by the Westinghouse Electric & Manufacturing Company. They are generally set to

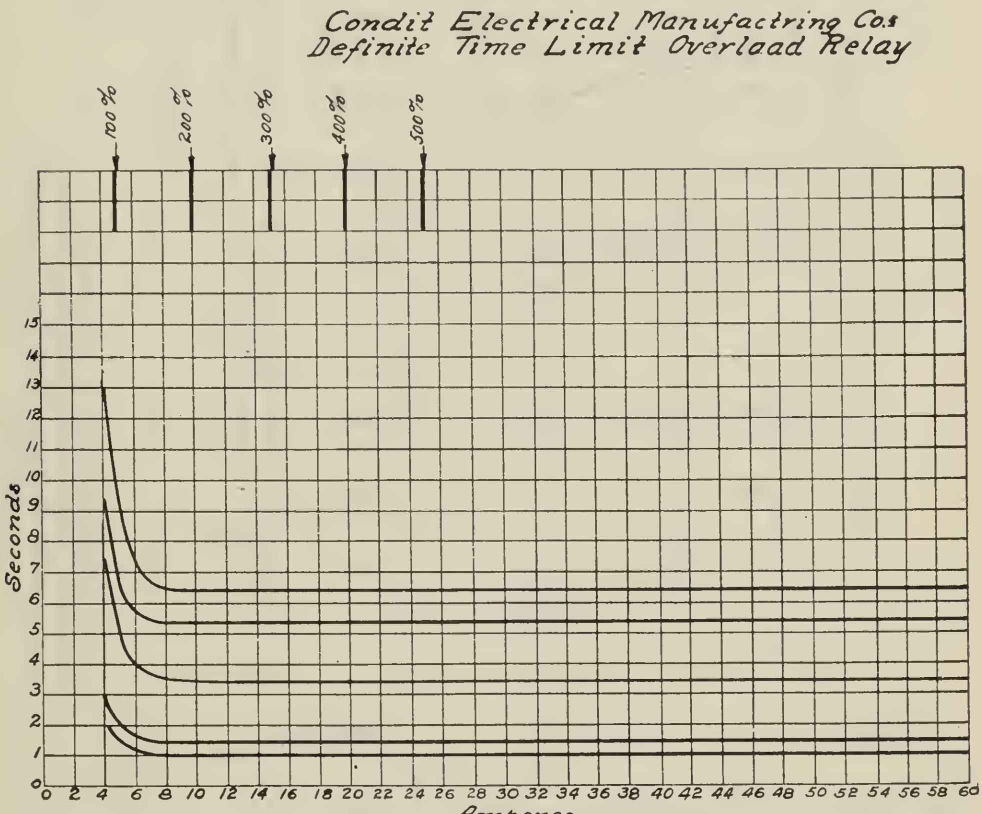
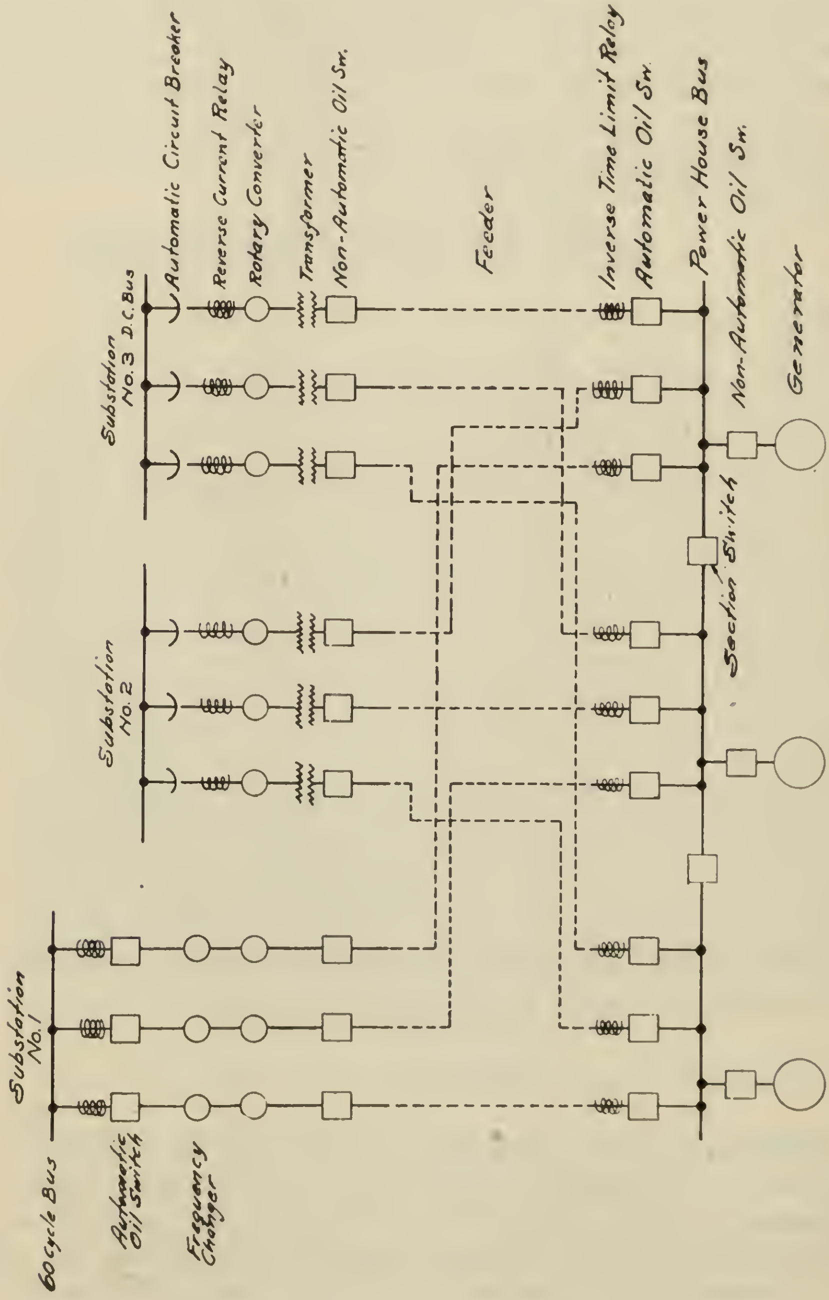


FIG. 3

open the switch after two seconds with about twice the normal carrying capacity of the cables or lines. Under a heavier current,—as, for instance, a dead short circuit,—they would operate in a fraction of a second, or at a speed inversely proportional to the overload. In some cases, however, as when several sub-stations are connected in series, a definite-time-limit-overload-relay is used such as that of the Condit Electrical Manufacturing Company, a performance curve of which is shown in Fig. 3. The bus or buses supplying the feeders must be maintained alive under all conditions of operation, even at the risk of the generators, and, there-

fore, the oil switches connecting the generators to the bus or buses are not usually automatic but are hand operated. Any generator in trouble can usually be cut out of service by the switchboard operator without injury to other generators operating in parallel



Typical Diagram of Connections Showing Power House and Substations with Radial Feeders and Overload Relays
Fig 4

with it and without interruption to the service, because an appreciable time is generally taken after a fault first starts to completely break down the insulation of the generator windings.

Where step-up transformers are installed in the power house,

either inverse-time-limit-overload-relays or reverse-current-relays are used. Motor generators, rotaries, frequency changers, etc., in the power house and sub-station are usually connected to the A. C. bus or buses through automatic oil switches controlled by

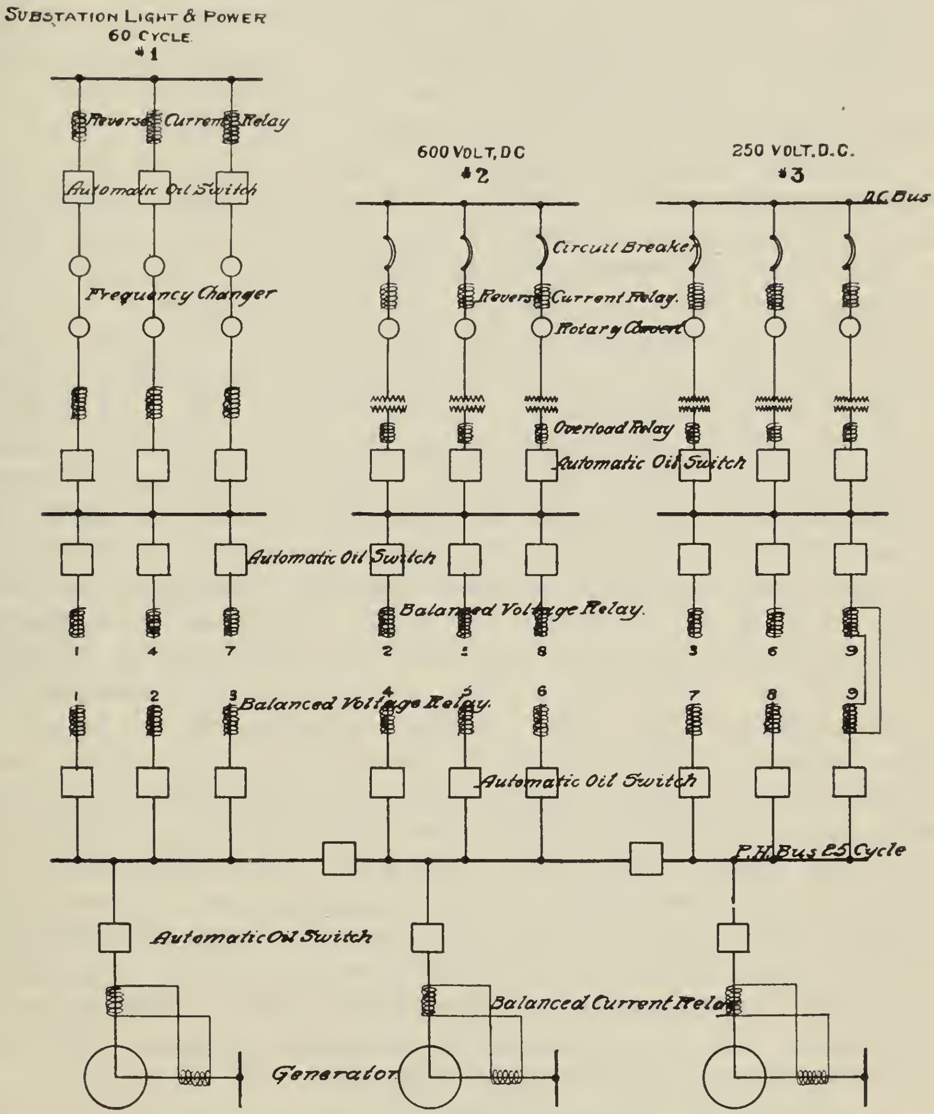


FIG 5

TYPICAL DIAGRAM OF CONNECTIONS
SHOWING POWER HOUSE AND SUBSTATIONS
WITH PARALLEL FEEDERS AND BALANCED RELAYS

inverse-time-limit-overload-relays and to D. C. buses through reverse-current-relays. All light and power feeders from the substation are also provided with these automatic oil switches, the relays being set to protect the load they supply usually at twice their

maximum load. Diagrams of connections for power house and substation are shown in Figs. 4 and 5.

The excellent service rendered by practically all the large electric companies operating under the above general conditions would make it appear unnecessary to provide further protection. Too much credit cannot be given the operating engineers for the results obtained. Occasionally, however, interruptions in service are unavoidable and are sometimes followed by serious damage to apparatus. Anything that will increase the reliability of service and add protection to the apparatus is, therefore, of interest.

The ideal relay and switch combination would be that which would instantly cut off a feeder suffering any defect. This ideal today is only realized in such systems as railway systems where the circuit-breakers can be set to trip instantly; and they do so no matter whether the actuating impulse results from a sudden load swing or a short circuit. In power distribution from a generating station to sub-stations or to general distribution systems, of course similar methods are impracticable. They are impracticable for the reason that a relay designed to operate instantaneously gives, with its oil switch, a time element approximating one-quarter of a second for the solenoid type of oil switch, and one-half of a second for the motor type of oil switch as set forth in the paper of E. B. Merriam before the 1911 Chicago Convention of the A. I. E. E. This time element is the time from the beginning of the short circuit until its end, as indicated by the oscillograph curves. The major portion of this time is consumed by the mechanism of the switch itself, or, figuratively, in the muscle of the animal. Therefore, in the event of a short circuit every automatic in the system may receive an impulse which is transmitted to its muscle for performance before those particular automatics that should operate have freed the system from the short. In other words, instantaneous relays cannot be made successfully selective. This type of relay also cannot be made to distinguish between a swing lasting two or three cycles, as at times of synchronizing, and a short circuit lasting indefinitely; that is, the relay cannot discriminate. The defects of the instantaneous relay are then, that it does not select and does not discriminate.

To make the automatic selective, the inverse type of relay and the reverse current type of relay were developed. The inverse-time-limit has a time element whose action is quicker the larger the overcurrent flowing, in approximately inverse ratio. This makes the automatics controlling the defective piece of apparatus more or less selective, and to a degree discriminating. They must be set to operate only on an abnormal and generally a dangerous overload. Therefore, a fault must develop to a degree dangerous to other cables or apparatus before the relay begins to act; and even under a dead short circuit to ground or to adjacent con-

ductors the relay cannot operate the oil switch instantly, but requires, say, one second of time. The time element of the oil switch, moreover, is from 0.2 to 0.6 of a second. It generally happens in such cases that the oil switches of other feeders operating in parallel are also opened, shutting down the sub-station and all its apparatus. For this reason some of the largest companies do not operate the feeders to a given sub-station in parallel, but they operate them radially, each feeder supplying current through a sectional bus to one or more rotaries or other apparatus units. The Commonwealth Edison Company, while adhering to radial operation of feeders, have, on their 25 cycle feeders, applied a little poppet safety valve to the air dash pot of the inverse-time-limit-overload-relay which permits instantaneous operation of the relay when the current reaches 300 per cent of continuous carrying capacity of the cable. This is, in a way, objectionable, as the oil switch may have to interrupt an enormous instantaneous flow of energy in the case of large generator capacity behind the feeder, and not only must the oil switch be capable of performing this operation, but the interruption itself may cause abnormal potential strains on the whole system. The results are less serious, however, than the short circuit, and this feature is, therefore, adopted. The 25 cycle feeders are of 9,000 and 19,000 volts potential, and 60 cycle feeders are of 12,000 volts potential and are further described in a paper by R. F. Schuchardt, presented at the Chicago Meeting of the American Institute of Electrical Engineers, June 5, 1908, as follows:

> "The transmission feeders, with a few exceptions, consist of three conductor 4-O cable. The relays on these lines are based on a continuous carrying capacity of 250 amperes, which is 3,900 k.w. at unity power factor. A 300 per cent load on this basis is considered sufficiently high for instantaneous action of the relay and 225 per cent load for two seconds. The minimum current on which the relay will operate is taken at 160 per cent load. A 4-O line may be loaded up to 4,000 k.w., therefore the minimum setting is increased somewhat above one-half the instantaneous setting. In our substations we have removed or omitted the line relays entirely. Instead, the lines all feed separate buses in the sub-station and are not ordinarily connected in parallel at that end. Dependence is thus placed on the relays of the units themselves for disconnecting the line from the load in case of trouble on that line. A 2,000 k.w. unit, either rotary converter or frequency changer, on which the full load input current at unity power factor is 155 amperes, has its relays set at 310 amperes minimum, 465 amperes in two seconds and 620 amperes instantaneous. Smaller units are set on this same basis in proportion to their capacity.

"The relays on the 60 cycle circuits and generators of the frequency changer sub-stations do not have the instantaneous attachment, and the overload settings are higher in proportion than on the 25 cycle relays. The principal reason for this is that the short circuit characteristics of the generators are different from those of the 25 cycle turbo-generators, and the possible energy which can flow into a 'short' is not sufficient to endanger the machines. Also, on 60 cycles the relay acts fairly promptly on excessive overloads. The voltage of these 60 cycle, 4-wire, 3-phase generators is 4,150 volts delta, and their full load rating is based on 75 per cent power factor. A 2,000 k.w. generator would thus be rated at 372 amperes full load current. On this unit the relays are set at a minimum of 840 amperes, and 1,200 amperes for two seconds. Other sizes of 60 cycle generators have their relays set similarly in proportion to their rated capacity."

The New York Edison Company, with 6,600 volts, 25 cycles potential, operate all feeders radial with ungrounded neutral, the oil switches at the power house and sub-stations being protected by inverse-time-limit-overload-relays. All feeders are underground cables. At the power house each feeder is provided with a fault detector designed by P. Torchio, chief electrical engineer of the company. This detector consists of a suitable coil slipped over the lead-covered cable and is affected by any capacity current that might flow in the lead sheathing. Normally the capacity between each conductor and the other two conductors, and between it and the earth, are relatively the same. Therefore, under normal, healthy operating conditions no capacity current flows in the lead sheathing of any of the feeders. If, however, a ground or a short between any two conductors occurs, the electrostatic equilibrium will be disturbed. Assume that a ground develops on one conductor of any feeder;—the capacity of this particular phase of the whole system to ground becomes zero, while the lead sheathing of all the feeders acts as a return circuit to the fault for the capacity current due to the electrostatic capacity of each of the other two conductors to ground.

In the case of the New York Edison Company's system there are several hundred miles of 6,600 volts, 3-conductor cable, and it is possible for this capacity current to reach 100 amperes. The detectors are adjusted to ring an alarm and operate an annunciator showing the number of the feeder affected when the capacity current reaches 10 amperes. The switchboard operator can generally cut out the feeder at the power house end, and telephone the substation operator to cut it off at that end before serious trouble develops. These fault-detectors do not operate the switches and cannot be used on a system with grounded neutral. They are best adapted for a large system having considerable capacity. The elec-

trostatic equilibrium is sometimes unbalanced from some external cause, resulting in operating the alarm. This is easily determined by testing the cable after it is cut out of service. These fault-detectors have been installed on all feeders at the power house end for more than two years and are operating satisfactorily.

The advantages of a relay that can discriminate between a fault and an overload, and that can cut out a faulty circuit or piece of apparatus before it has developed a serious power flow, are evident. The Merz-Price protective gear, named after its inventors, performs these functions. Any feeder or apparatus protected by it is promptly cut out of circuit simultaneously at each end, generally before the power flow becomes abnormal, while it is not affected by any healthy overload of power flowing in either direction. In other words, it protects the apparatus and the continuity of service against faults of all kinds, but not against overloads. As practically all interruptions to service and damage to apparatus are due to faults and not to temporary overloads, the Merz-Price protective gear offers the protection desired in heavy power circuits.

The system is based on the principle that while normally the amount of current leaving a conductor at one end is equal to that which enters it at the other, as soon as a fault or leak develops this equality disappears. By inserting current-transformers at both ends of each conductor of the cables, and connecting their secondaries in opposition by means of pilot-wires with relays in circuit, it is made possible, when, due to a fault, the balance between the two sets of current transformers is upset, and, in consequence, a current flows through the pilot-wire to trip the switches at both ends of the cable. In this way, as a fault affects only the particular pair of current-transformers on either side and immediately adjacent to it, causing a current to flow along the pilot wire connecting these transformers, the faulty section is isolated without disturbing any other. There are several ways of creating this balance of opposed forces applicable to various sets of conditions, but the principle remains the same in all.

With this system it is possible to obtain the full advantages of a duplicate supply, because the whole network may be kept continuously alive in the assurance that a faulty cable or other piece of apparatus will be isolated without in any way affecting the healthy duplicate, which will be thus left intact and automatically takes the load without even momentary cessation of supply. No matter how much current flows through a healthy section—*i. e.*, a section in which there is no fault—the balance in the pilot-wire-circuit controlling such section will not be affected. It should be noted that in addition to securing perfect discrimination between the cut-outs by adopting this system of protection, great economy in feeders has resulted, as it has been possible to adopt the principle of the ring

main in place of the radial system of feeders which would otherwise have had to have been used.

In order that the relay may not trip out on transient swings,

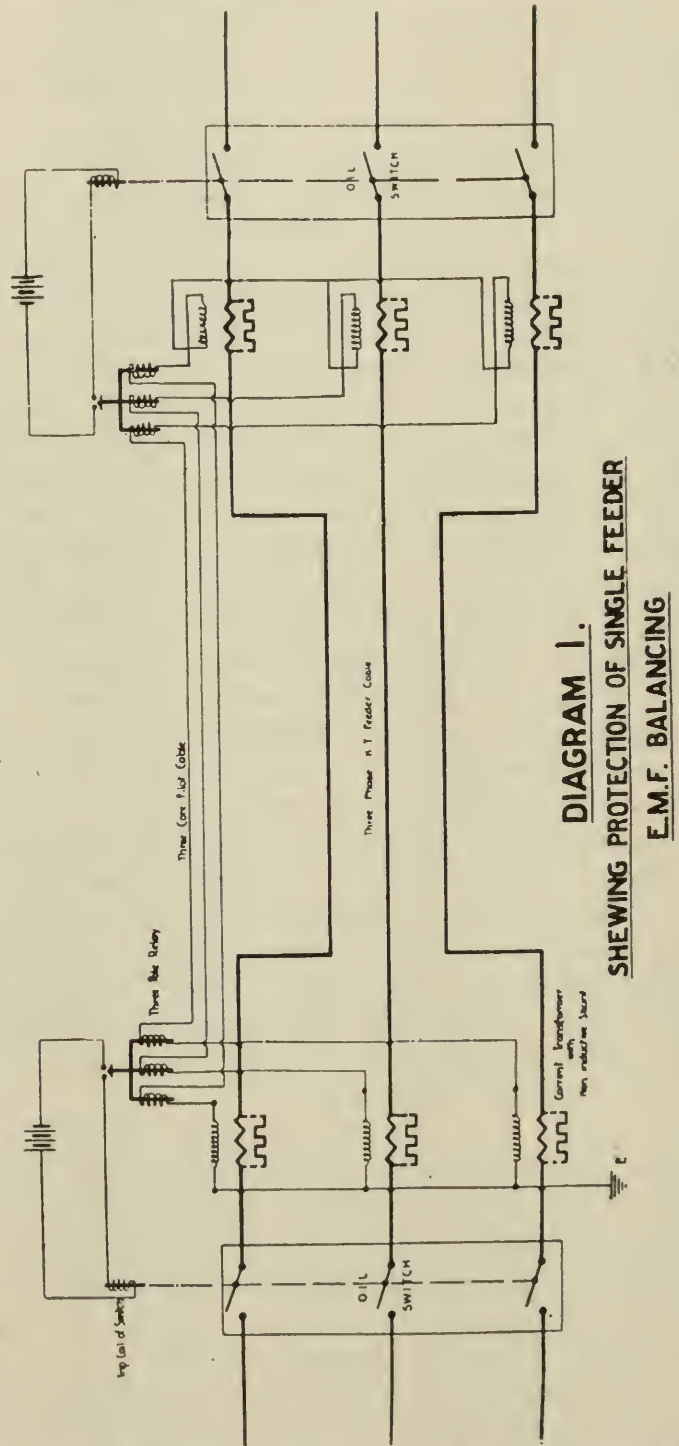


DIAGRAM I.
SHEWING PROTECTION OF SINGLE FEEDER
E.M.F. BALANCING

it is obvious that a period of about one-half to one second is the shortest time-interval that can be hoped for in either the definite or inverse-time-limit-overload-relays.

The Merz-Price relay is not affected by transient swings, so that a speed of action impossible with the others may be obtained.

Merz-Price Gear.

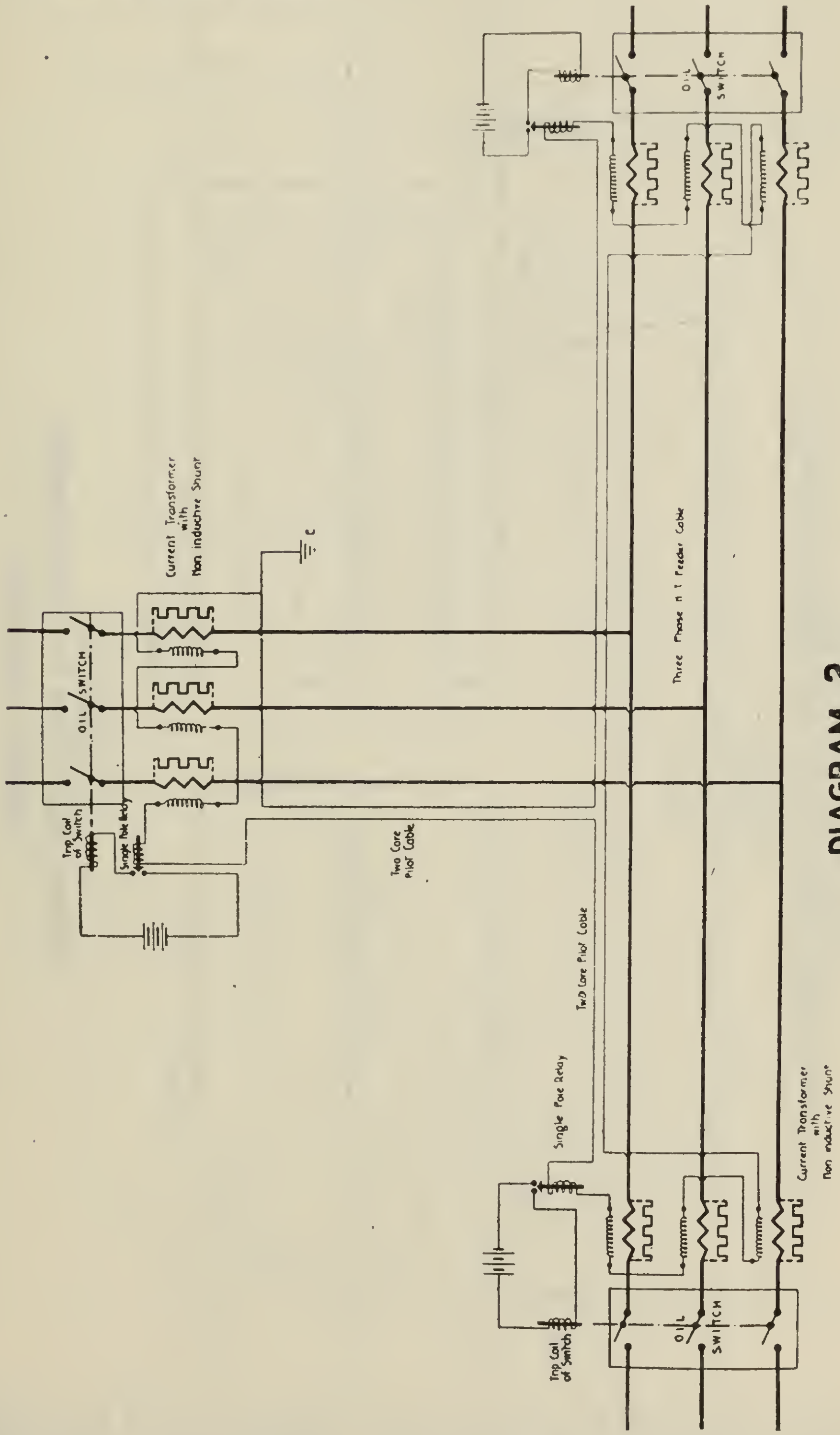


DIAGRAM 2.
SHEWING PROTECTION OF BRANCHED FEEDER
E.M.F. BALANCING

The only theoretical limitations appear to be the speed of propagation through the pilot-cable, and the best speed obtainable for the

switch and relay to operate after the relay has received its impulse.

It will be readily seen that the e. m. f. balancing is most ap-

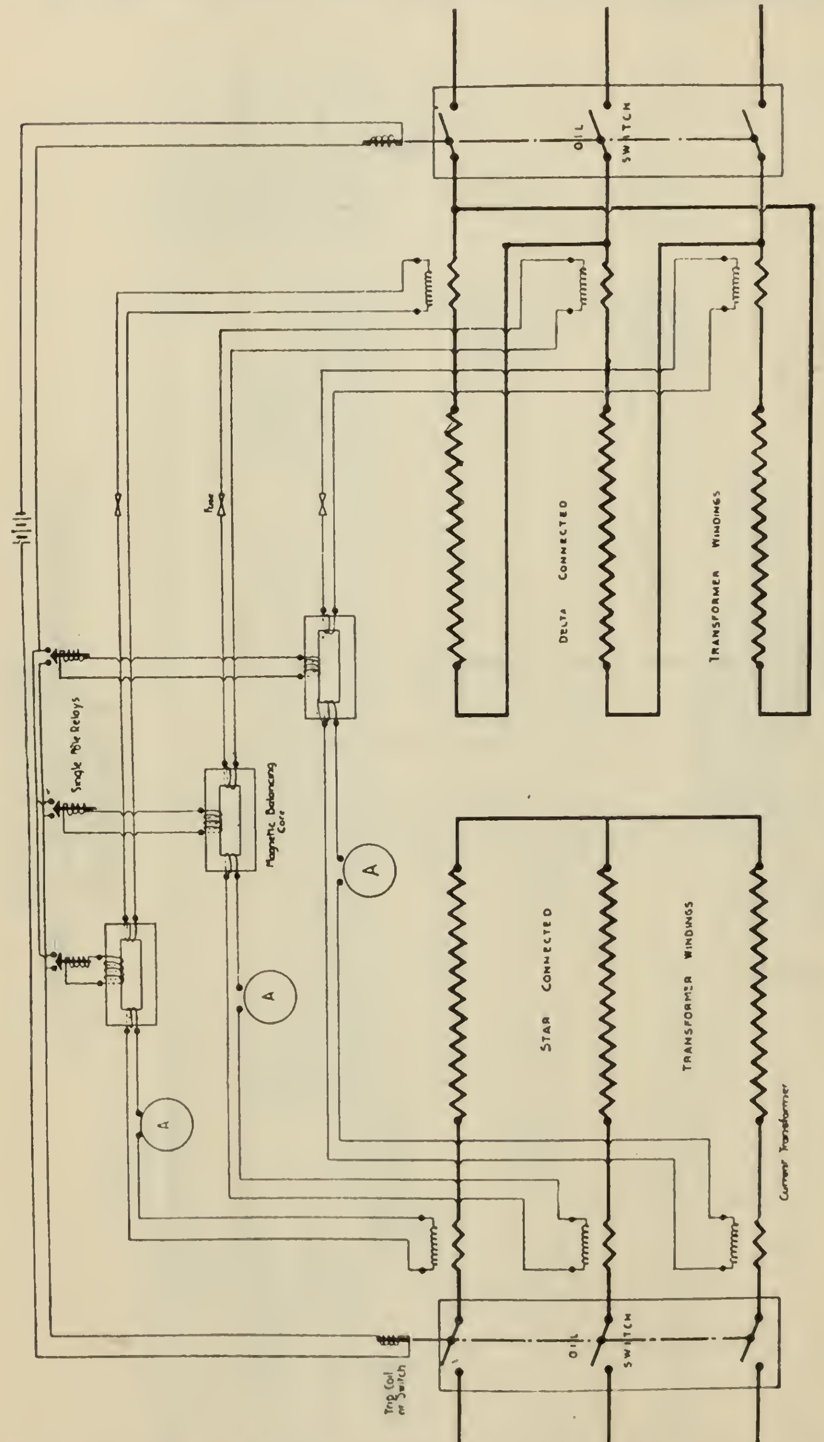
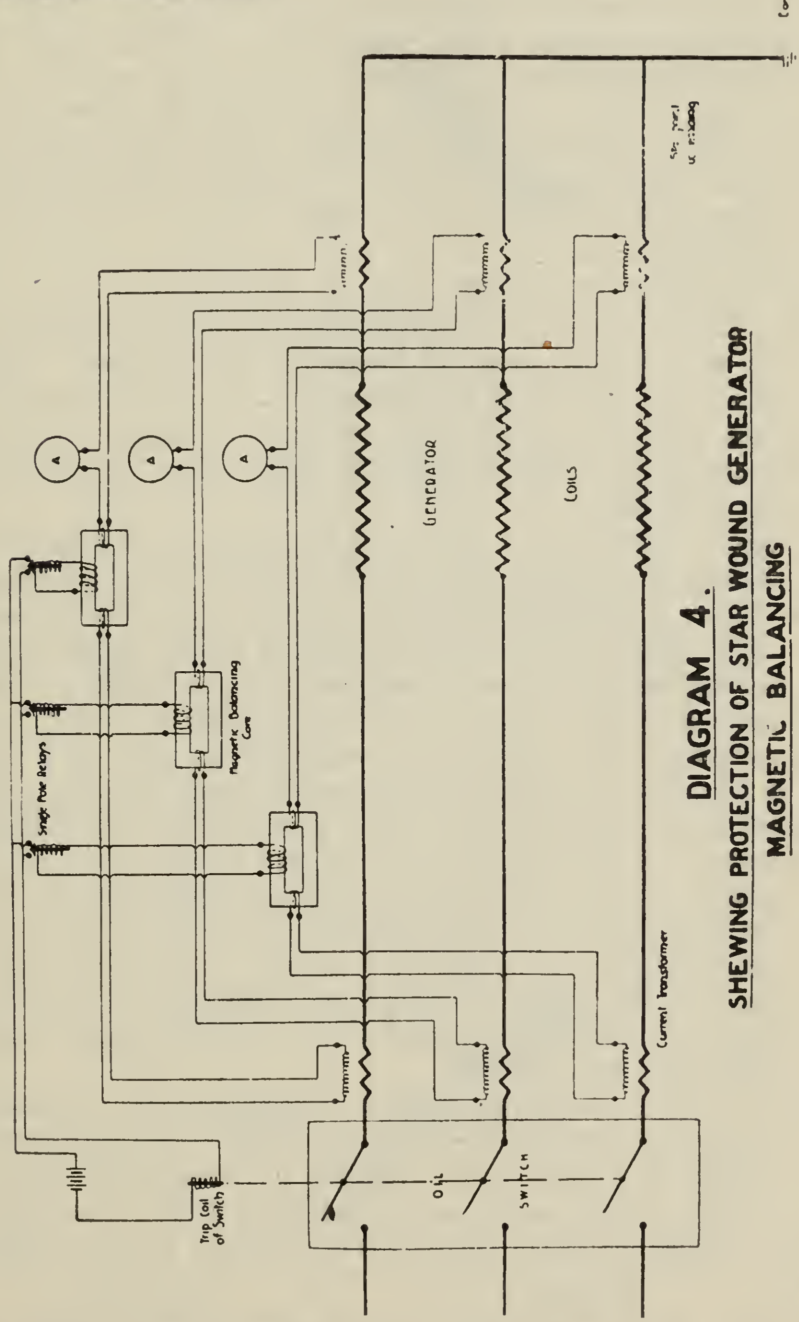


DIAGRAM 3.
SHEWING PROTECTION OF TRANSFORMER
MAGNETIC BALANCING

plicable to the protection of feeders (see Diagrams I and II), while magnetic balancing is best suited to the protection of transformers and other station apparatus. (See Diagrams III and IV.)

When magnetic balancing is employed for protecting apparatus, the switchboard instruments can be included in the current transformer circuits, avoiding the necessity of an extra set of transformers. The current transformers used must, however, be of

Merz-Price Gear.



ample current carrying capacity so as not to heat under heavy overloads. The success of the Merz-Price protective gear depends on the absolute reliability of the current transformers. A higher insulation factor, is, therefore, recommended than is general prac-

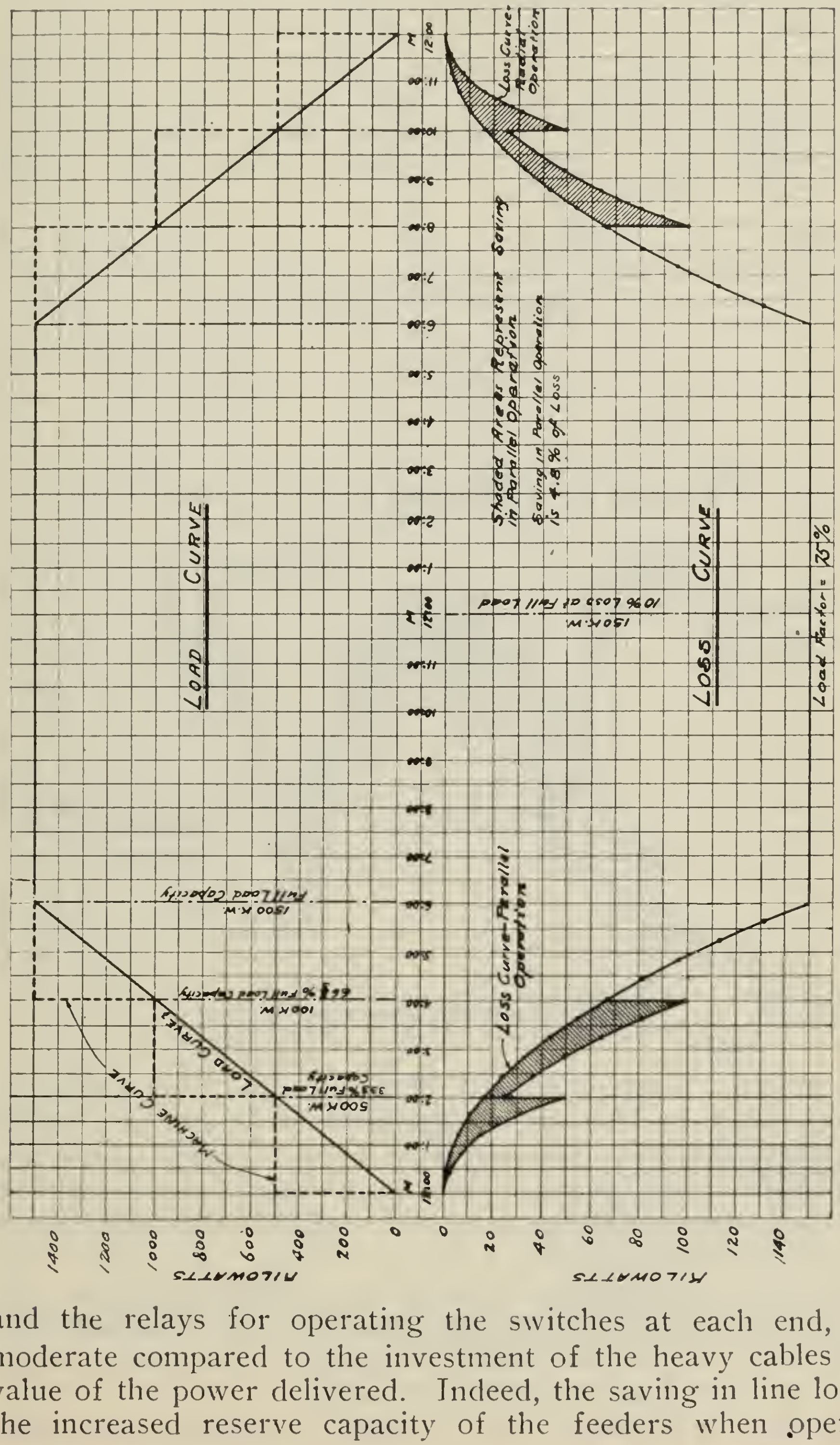
tice in this country. The transformers should be tested to a voltage five to six times the working potential. Where the magnetic balancing is used to protect apparatus, it is usually found desirable to especially design the current transformers for low heating and high insulation. These same current transformers may supply current to all switchboard instruments and, therefore, only the relays and little balancing relay transformer solenoid trips are required above the standard switchboard equipment, and the cost for the protection is little, if any, more than for the reverse-current-relays now used. Reverse-current-relays, while very effective in selective action when the power flow is reversed under normal load conditions, may fail to properly act under extreme overload or short circuit conditions.

The reverse-current-relay has a potential coil and a current coil. Under normal load conditions the magneto motive forces of the two coils are opposed and balance one another. In case a fault develops in one of the windings of the large transformers, and current rushes in from both ends of windings, the potential coil aids instead of opposes, and the relay works, opening the oil switches at both ends.

On short circuit the voltage and the power factor may be very low, resulting in greatly reducing the effect of the potential coil, and the relay becomes simply an overload relay with uncertain action. The Merz-Price protective gear is better adapted than the reverse-current-relay for the protection of alternating current apparatus such as large transformers and generators. A set of current transformers are, of course, required on each end of windings. In the case of transformers on the high and low windings, the ratios of the current transformers must be such as will produce approximately the same secondary currents in each set. In the case of generators, if the stationary armature windings are *Y* connected, the inside end of each winding must be brought out to a current transformer and from the current transformer to the *Y* connection. In the case, therefore, of large generators three additional transformers are required that are not used in connection with switchboard instruments.

The e. m. f. balancing is best adapted to the protection of cables, because the secondary windings of the current transformers are in opposition so that their voltages balance and, except in the case of a fault in the cable, no current flows in the pilot-cable. By the proper design of these current transformers and the relays used in connection with them, suitable voltages can be obtained in their secondaries for reliable operation over many miles, using a 3-conductor pilot-cable of No. 10 or No. 12 B. & S. conductor. This pilot-cable is the one objection to the Merz-Price protective gear. It costs laid, not including ducts, from $800.00 to $1,000.00 per mile. Where a number of feeders run to the same sub-station,

the pilot-cable for each can be carried in a single duct. In most large central station plants one or more spare ducts are available. The cost of duct space will run from $100.00 to $250.00 per mile. The cost of the special current transformers at each end of cable



THEORETICAL LOAD AND LINE LOSS CURVES FOR RADIAL AND PARALLEL OPERATION
FIG 6

and the relays for operating the switches at each end, is very moderate compared to the investment of the heavy cables and the value of the power delivered. Indeed, the saving in line losses and the increased reserve capacity of the feeders when operated in

parallel instead of radially, in many instances largely compensates for the first costs of pilot-cable and current transformers. Frequently, one or more spare cables are run from power house to sub-station for emergency use only. These could be dispensed with, or, if already installed, they could be always in service in parallel with the other cables with a proportionate reduction in line losses. In radial operation, each feeder and the apparatus to which it is connected may be considered a unit. Normally, when the apparatus is not in service the feeder also is idle. In cases of trouble in the feeders or the apparatus, the healthy feeders

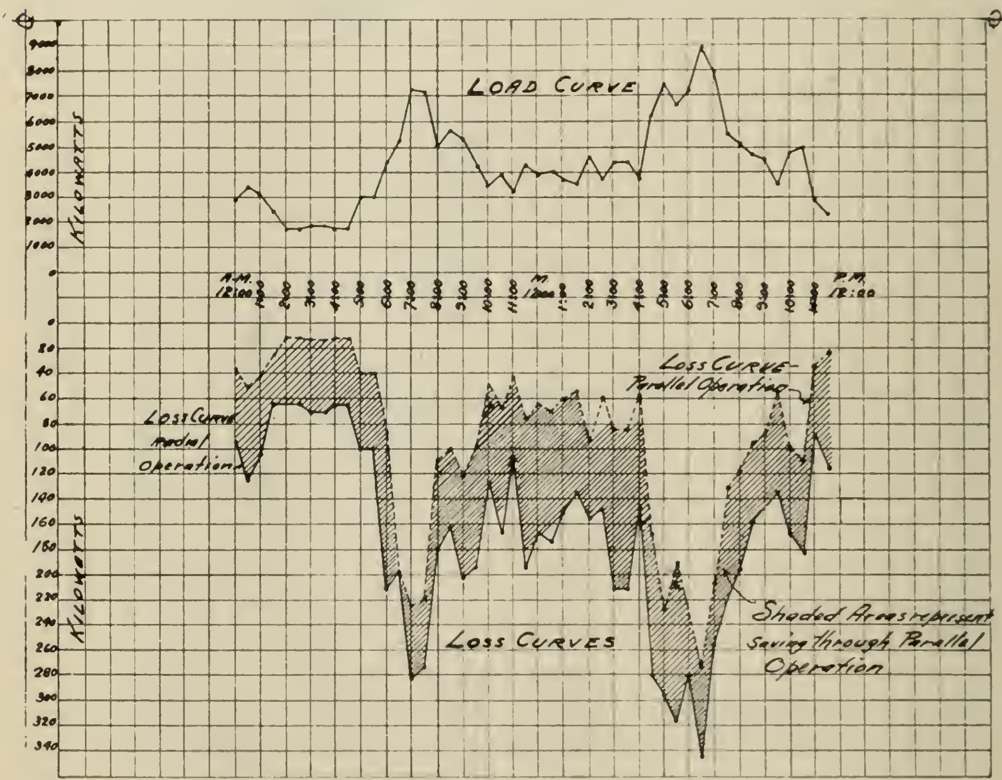


Fig. 7

Typical Load and Line Loss Curves for Radial and Parallel Operation

can be connected through transfer buses to almost any apparatus, and if necessary the feeders can temporarily be run in parallel, but the large companies normally operate the feeders to the substation radially. Figs. 6 and 7 show graphically the per cent saving in line loss by parallel operation as compared with radial operation.

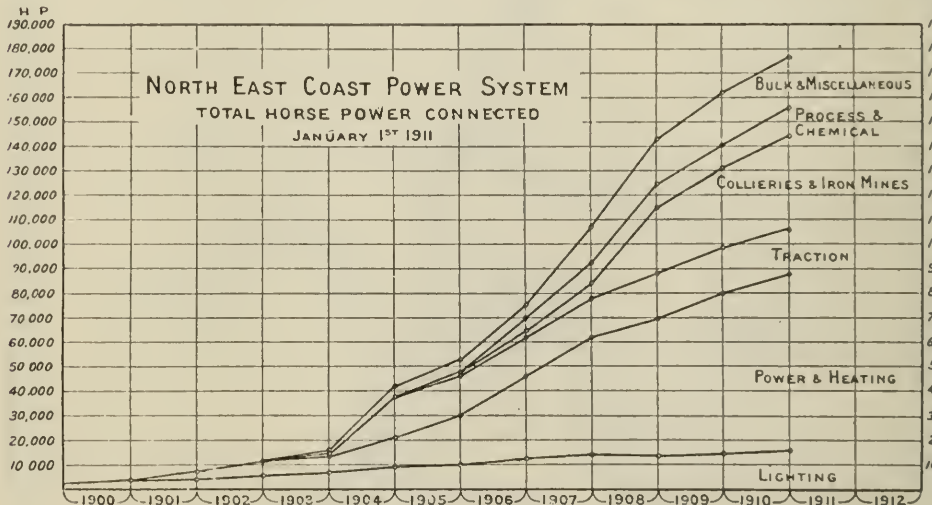
The increase in reserve capacity by multiple operation over radial operation, depends upon the capacities and arrangement of sub-station units as compared with the capacity of the cables; it will probably run from 5 per cent to 15 per cent.

A further reduction in line loss and an increase in reserve


MAP SHOWING
NORTH EAST COAST
POWER SYSTEM
SCALE OF MILES
0 2 4 8 12 16
REFERENCE
20,000 Volt Cables shewn thus
11,000 " " " "
6,000 & 3,000 " " "
Power Stations " "
Substations " "
Companies' boundary " "
MORPETH
BLYTH
CARVILLE
NEPTUNE BANK
WALLSEND
TYNEMOUTH
SOUTH SHIELDS
NEWCASTLE ON TYNE
BLAYDON
DUNSTON
GATESHEAD
SUNDERLAND
PHILADELPHIA
DURHAM
SHOTTON
HORDEN
BANKFOOT
BOWDEN CLOSE
CASTLE EDEN
WEARDALE
HARTLEPOOL
WEST HARTLEPOOL
BISHOP AUCKLAND
PORT CLARENCE
REDCAR
SALTBURN BY THE SEA
AYRESOME
GRANGETOWN
STOCKTON ON TEES
NEWPORT
MIDDLESBROUGH
TEES BRIDGE
GUISBOROUGH
BARNARD CASTLE
DARLINGTON
RICHMOND
R. Blyth
R. Tyne
R. Wear
R. Tees
R. Swale
R. Leven
R. Skerne
R. Wiske
D U R H A M
2°
1°
55°

feeder capacity can be frequently effected by tie lines between sub-stations, these protected by the Merz-Price balanced voltage gear. (See Figs. 4 and 5.) Where a number of sub-stations require less than the increased capacity of a single feeder they may be ring connected; each section of feeder being protected, continuity of service is provided and any section may open without interrupting the service.

The considerable expense of the pilot-cable will probably limit the use of the Merz-Price protective gear to heavy power circuits from power house to sub-stations of other sections of distribution; also for tie lines between power houses and tie lines between sub-stations, and especially where several sub-stations are supplied with power from the same feeder or feeders in ring connection. The writer also believes it a desirable protection for large



turbine generators and large banks of transformers. He recommends the use of overload relays of the inverse-time-limit type on outgoing feeders from power house to sub-stations and on light and power circuits of sub-station apparatus.

The e. m. f. balanced gear for cable protection requires periodic inspection to insure its being in operative condition, as it is of the open circuit type. The magnetic or current balanced gear for the protection of apparatus does not require the same inspection, as it is of the closed circuit type.

The Merz-Price protective gear has been in successful operation in England for more than four years. The principal installation is on the Northeast Coast Power Company's system in the vicinity of New Castle. Here 17 steam turbine power stations, having a generator-rating aggregating 120,000 k.w., supply power to more than 150 sub-stations. The distribution system covers a territory approximately 35 miles long by 10 to 15 miles wide, as shown in the map. It is the consolidation of several power com-

panies, each employing different line voltages including 20,000, 11,-000, 6,000, and 3,000 volts. All lines and cables are operated in parallel, through transformers where necessary, protected by the Merz-Price balanced voltage gear, while some of the larger turbo-generators are protected by the magnetic balance gear. More than 1,000 sets of protective gear are in operation and give perfect protection and uninterrupted service. While some of the lines are

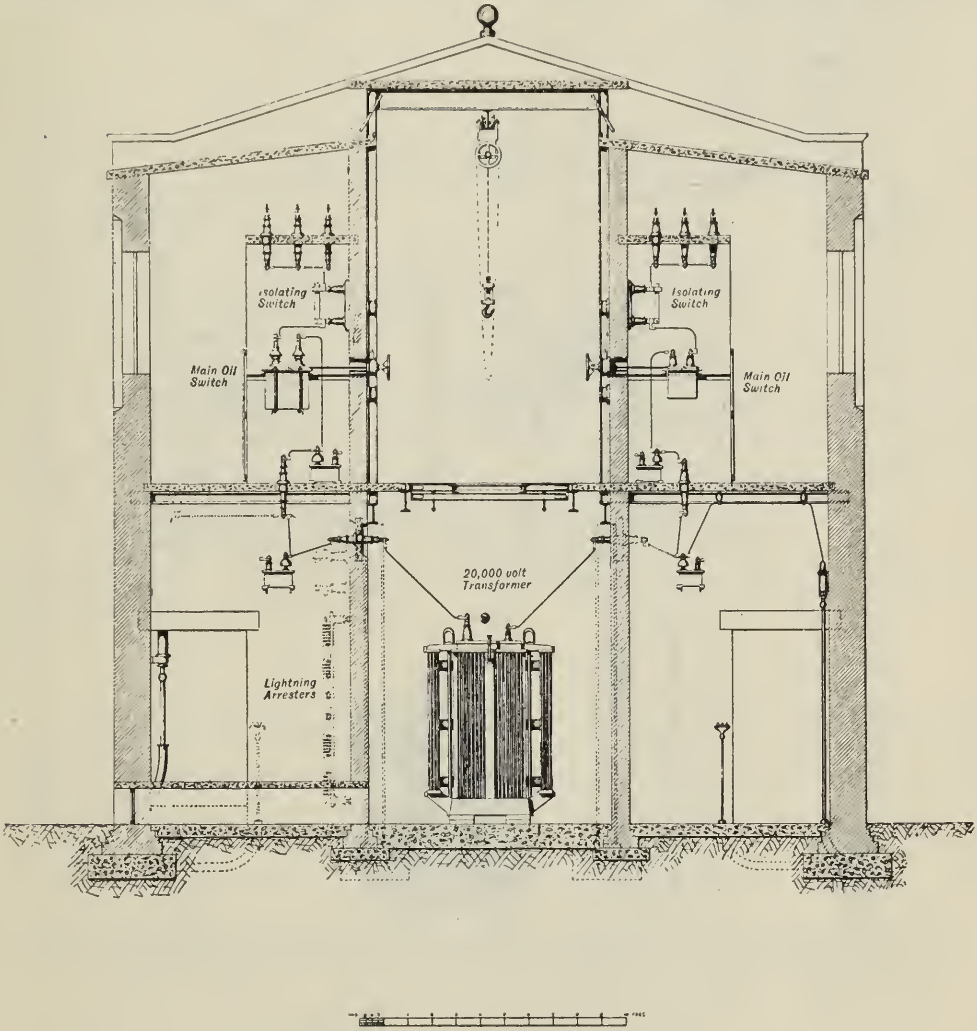


Fig. 34.—CROSS SECTION OF SUB-STATION.
Converting from 20,000 volts 3-phase to 6,000 volts 3-phase.

Fig. 8.

overhead, many are underground. Eleven of the power houses utilize the waste heat from coke ovens or take the exhaust steam from large blowing engines in steel plants.

The power is delivered to one large distribution system through feeders, from each of the power houses operating in parallel and so protected as to insure uninterrupted service with minimum line losses. Every variety of industrial power and commercial lighting is secured on a rate basis profitable to the customer and the com-

pany. In this connection the ironclad switch gear designed by Merz and Price, and quite generally used in the power houses and sub-stations of the Northeast Coast Power Company, is of interest. A cross section of a sub-station equipped with standard high ten-

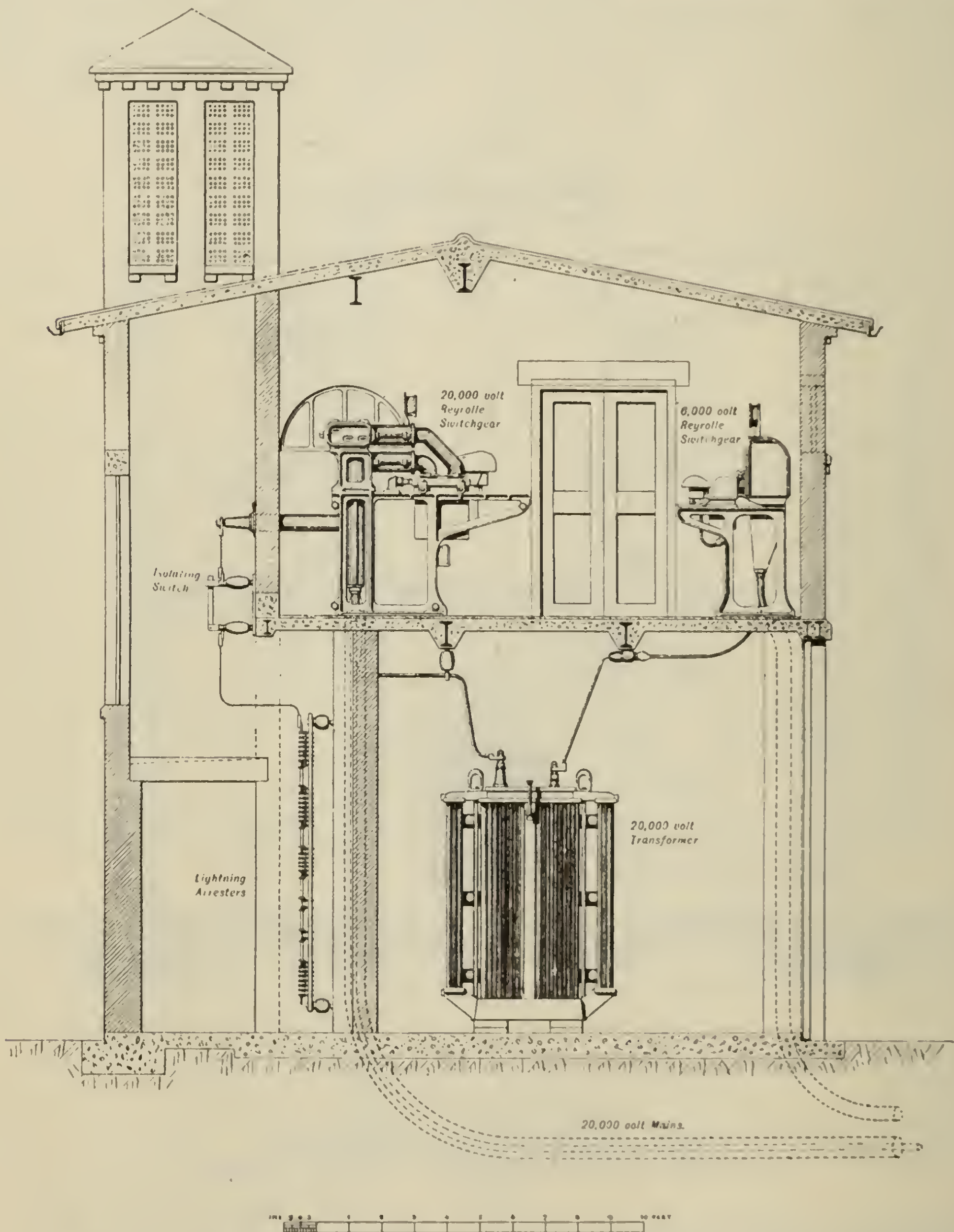


FIG. 35. CROSS SECTION OF 20,000 VOLT SUB-STATION.
Latest type, with "Ironclad" Switchgear.

Fig. 9.

sion bus and switches, and a sub-station equipped with the ironclad switch gear and bus are shown in Figs. 8 and 9. The switch gear is used on voltages up to 20,000 volts. It occupies considerably less space, is quite fire-proof, requires practically no cleaning, and

is "fool-proof". Oil switches are used similar in design to our standard types and aranged so that they cannot be touched or even withdrawn for inspection or cleaning until the circuit is broken. In this gear the designers have entirely abandoned the use of slate or marble panels or bare conductors of any kind, and substituted a metal frame-work and box, in which all conductors are encased, the terminals being fixed in porcelain. The cables enter by ironclad trifurcating boxes fixed underneath the gear at the back, and inside of which are fitted the current-transformers. The actual oil switch is mounted on a carriage running on steel rails or brackets at the side, so that it can be withdrawn for examination, complete with its operating-gear, oil-tank, etc. This breaks contact on two knife edges, the live contacts being at once automatically covered by two cast-iron flaps. It is impossible to break contact, however, until the main oil-break switch has been opened, and impossible to close the oil-break switch until the switch has been replaced in position in the contacts. The oil-break switch contacts consist of rows of small separate blocks about ½-inch in width, arranged with self-cleaning sliding contacts. The ironclad switch gear has much to recommend it, especially for sub-station use, in small towns where inexperienced men may be employed, space reduced, and probably a considerable saving in first cost obtained over our present standard practice.

The writer desires to acknowledge the courtesy of Mr. Merz in furnishing the illustrations and much information on the control and the switch gear described.

Discussion.

R. F. Schuchardt, M. W. S. E.: Mr. Lyman has given us a carefully prepared paper, on a subject which is timely and which will remain timely until the solution is reached. This is the first time that a detailed description of the British work has been presented at an American meeting, and the paper is therefore particularly interesting and perhaps also particularly timely, as it is presented at the close of the year during which one of the inventors, Mr. Merz, made an American tour.

I am sorry to note in the ampere-seconds curve that the author has not used the conventional form in which "time" is assumed to be going from left to right in the horizontal direction, that is, the abscissæ of the curve. Mr. Lyman unfortunately has plenty of precedent for the reversal, however. There does not seem to be the proper unanimity on this that there should be. It seems to be a repetition of the clockwise and counter-clockwise diagram muddle, which finally had to be settled in international congress.

In the paper is a very clear description of the action of oil switches. It does not matter what means are used as nerves to get the impulse transmitted into the muscles of the switch. It

is the switch that really must do the work after it gets the message. The switch cannot be made to open absolutely instantaneously. It must take some definite time for the message to be transmitted and the action to take place. There is also a question of whether we want absolutely instantaneous action of the switch. We know that the more sudden an interruption is and the greater the current interrupted, the greater the probability of a surge and serious disturbance. It is quite probable that delayed action of a switch on a system that is provided with current-limiting devices, such as reactances and neutral resistances, is, under present conditions, the most satisfactory.

The paper also contains a brief chapter in the history of American relays. The pop-valves which the Commonwealth Edison Company used several years ago were put on primarily to obtain greater reliability of the relay, not particularly to obtain the instantaneous action. That was a secondary result, which, under existing conditions, was also desirable. But even the addition of the pop valve, while it made the relay itself far more reliable than it was at that time (and the relay has since been perfected more by the manufacturer also), did not make it selective. The demand for a selective relay resulted in the Condit relay being brought out. This resulted in the General Electric Company perfecting its own relay and turning out one which, it is claimed, is really selective. It is built, I believe, with a conically-shaped core so that the pull is approximately the same at the different points of its travel. This is a step in the right direction.

In my paper of two and a half years ago, referred to by the author, I described the Commonwealth Edison system as it was at that time. Today we have over 500 miles of transmission line and over 60% of that is in 250,000 circular mil cable. The relay settings on this cable are based on current capacity of 300 amperes, the percentage of the settings being the same as given in that paper.

The Merz-Price scheme is an excellent and ingenious one, and is thoroughly worked out. In its proper place it is very good, but not, as some enthusiasts believe, a cure-all for the troubles in operating a large system. Its great advantage, of course, is the complete selectiveness when it works. Its ability to cut out a fault before it has developed to large proportion is another great advantage. This is possible in protecting transformers, for instance, where the breakdown may be in the form of a limited arc for a short interval, during which the relay trips and prevents a more serious breakdown and destruction.

On cable breakdowns, as far as our knowledge at the present time shows, I doubt whether the switch—even if it were so-called instantaneous—could be made to operate quickly enough through its relays to cut off the circuit before the fault had reached its

maximum. With the present arrangement the fault current passes the maximum and comes down on the decreasing slope before it is cut out. We know, and have known for eight or nine months, since the experiments at Fisk street, that switches can be designed to handle most of the cable breakdowns.

The principal disadvantage of the Merz-Price scheme, as Mr. Lyman has clearly pointed out, is the high cost of the pilot wires. Another disadvantage is that it is in the opposite direction from that which all central-station engineers want to go, in regard to simplicity. It is putting greater dependence for reliable operation on a larger amount of apparatus, and, in addition, on pilot wires from station to station. This is a serious matter and especially since, when the scheme is applied, we must put total dependence on this device, and its connections. Possible operating troubles due to capacity current and the third harmonic circulating around through the pilot wire circuit and therefore through the relays, are perhaps objections, though apparently most of these problems have been solved.

The need for separate current transformers is another objection, especially where a large investment has been made in present current transformers. We must cut into the high tension leads and connect in these additional current transformers—for the other transformers are retained—of a special type for these relays.

An opening in the circuit of the pilot wires of the relays is not detected, because the scheme is based upon "open circuit" operation. In the magnetic balance form, a closed circuit is used, but this form is not used between stations because of the large size wire necessary for the current. The current transformers which are connected with the pilot wires are at both ends of the line or on both sides of the transformer, but the bus bars and the switch gear themselves are absolutely out of that zone of protection, and we know that occasionally a small animal will stray too near a switch and cause trouble. Messrs. Merz and Price have provided for that by making the switch gear ironclad, which the author has explained to us. Both of these men have shown themselves to be exceedingly clever and level-headed engineers, and they approach their problems with a great deal of boldness. But the conditions of the North East Coast Power Company system are quite different from those in our modern large cities, although in the outlying territory that we are reaching into it is possible that some type of this especial construction is applicable.

The more we look into the practice of Europeans and Americans, in connection with cable protection, the more we realize that the greater freedom from trouble of the European systems is not due so much to the better protective devices used as to the higher grade of cable. The American manufacturers

have not made a cable which comes anywhere near the quality which the Europeans insist on getting from their manufacturers. The British Insulated Wire Company and the A. E. G. also, are prepared to make and guarantee under very rigid specifications a three-conductor cable for 40,000 volts, which is somewhat in advance of what American manufacturers will do.

Because of the high cost of the Merz-Price equipment, and particularly if applied to existing systems, it is necessary to find some cheaper method of protection, and it is earnestly hoped that the sort of talent which has been applied in developing this scheme will be directed toward designing a proper and satisfactory reverse current relay. With a relay of that type properly worked out, and with a selective relay that selects—as we have every hope to believe that the new relays will—we can protect most systems without pilot wires. Or, we can have ring systems of four elements with the pilot wires on only one of those four elements, or if consisting of more elements, with the pilot wire over all but three of them, etc. That is, we can work out a comparatively simple arrangement by putting the reverse current relays and the selective overload relays in the proper elements and then using the shortest line, the shortest section, for the Merz-Price attachments, resulting in a minimum cost and a maximum protection all around.

P. Junkersfeld, M. W. S. E.: I have been much interested in Mr. Lyman's paper and in what he had to say regarding the Merz-Price protective system. It, of course, naturally calls to mind the development of protective systems in this country. Some fifteen years ago, when the high tension underground transmission was first started in Chicago, the initial step was copper fuses on the low tension side of the transformers and nothing on the high tension side. That was quickly followed by snap-expulsion fuse blocks on the high tension side. A little experience quickly led to the conclusion that it was unwise to open up these high tension circuits except under oil, which then gave way to oil switches with instantaneous relays.

At that time the system was small and connected up on what was then called a tree system, which meant that a short-circuit anywhere on the tree in any of the branches, would cut out the main line at the power house and everything would go down. That, in turn, was quickly followed by a definite time limit in the form of a motor element that would control the relay and that would open only after the short-circuit or overload sufficient to trip the relay had been on a definite time—one second, two seconds, three seconds, as the case might be. That was followed by the bellows relay. This development all occurred in a period of perhaps three or four years.

The bellows relay was such a big improvement that we apparently all rested on our oars a few years, until we found that

even the bellows relay, while much better than what we had before, would not fill all the requirements. During this entire period, however, a great deal of work was done and a great deal of money spent in the direction of reverse current relays, but without conspicuous success. Messrs. Merz and Price started their work in England about eight or nine years ago, and I had the good fortune to see some of these devices in use five or six years ago, although the devices then were not in extensive use.

The Merz-Price system at New Castle-on-Tyne, England, is noted, the world over. It is a unique system in many ways and represents a great deal of business enterprise and sound engineering judgment. They have built up a very large power system right in the heart of a dense manufacturing and mining region. The industry consists very largely of ship building and metal working, manufactures of various kinds, and mining. Power is sold there on such a basis—and on an equitable basis—that even the collieries buy their power and utilize large motors for their hoists. In fact, there is so much power used there that it is the custom for users to buy power rather than make it—perhaps more so than in any other place in the world. In an engineering way this is only one of the many things they have there worked out.

Their system is a large interconnected one in which the power flows in different directions at different times of the day. There are two or three large generating stations, and in addition to that there are some eleven or twelve waste heat stations, the load on which is governed by the amount of waste heat available, which means that some hours of the day or some days of the month or year the power conditions may be entirely reversed. At certain times those waste heat stations actually take power from the system. At other hours and other days they deliver power to the system, which again brought about the necessity of a protective gear of this kind. The radial system that we use so largely in this country would not apply to that particular condition. It is the old story, "necessity is the mother of invention," and Messrs. Merz and Price have worked out a comprehensive system, including extensive and superior cable installations, which meets their own and similar conditions very well indeed.

In their ironclad switch gear, I think they have made a very decided advance, and one that is quite generally applicable in this country, much more so than the balanced relay scheme. It is safe, simple, easily taken care of, and possesses a great many advantages that no doubt will soon be worked out in this country as well. In fact, there are a number of Merz-Price switch gear equipments on order for at least two different cities in this country, which will probably be here very soon. I believe there is much merit in the general scheme of ironclad switch gear.

F. F. Fowle: The use of ironclad switch gear appeals to me particularly as a matter of safety. Of course, it means additional safety to the system from such accidents as those Mr. Schuchardt mentioned, which are sometimes caused by a small animal making a short-circuit with its body. But unless we have had occasion to examine the statistics of accidents and fatalities from electric shock or from burns—perhaps more particularly from burns—we probably do not realize the sum total of the loss of life in accidents, in the electrical industry. It is not, of course, a thing which we like to dwell upon, because that makes no restitution after the fact. However, we can take steps to prevent recurrence, and the use of protective devices of any kind to reduce the number of injuries and to save life, it seems to me, is our obvious duty.

In reference to ground detectors, I notice that the paper says:

> "Normally the capacity between each conductor and the other two conductors, and between it and the earth, are relatively the same. Therefore, under normal, healthy operating conditions no capacity current flows in the lead sheathing of any of the feeders. If, however, a ground or a short between any two conductors occurs, the electrostatic equilibrium will be disturbed."

And that disturbance presumably leads to a sheath current, which through the series transformer gives an indication in some form of instrument. I fail to see exactly how a mere short between conductors will give an indication, unless it is of such a severe nature that it causes an immediate disruption and destruction of the cable. If it starts as a high-resistance cross, I fail to see how initially it can cause any indication, because theoretically there would not be in that case any unbalance which would establish sheath currents.

W. L. Abbott, M. W. S. E.: After the Commonwealth Edison Co. had operated low tension apparatus ten or fifteen years with what was considered fairly good success in continuity of service, where a system shut down once in ten years was considered a bad record, we awoke with a distinct and unpleasant surprise when we began to generate 9,000 volts and at first had an interruption to that portion of our system every other day or thereabouts. It was several months, and I do not know but a few years, before we got used to the new stuff that we were handling and treated it with proper respect.

Among the problems which we have satisfactorily solved, is the protection of 9,000 volt lines. We have now become quite familiar with lines of that voltage, but the lines of higher voltage on occasion give us much trouble, and I think they will continue to do so until we have a better quality of insulation. I quite agree with Mr. Schuchardt's remarks, that our ultimate relief from this situation will be in better insulation rather than in a

protective device, which, however effective it may be at times, nevertheless adds what we call contraptions to the system. I believe the same amount of money which even this effective and relatively simple Merz-Price system would cost, if invested in better insulation of cables would be more satisfactorily spent.

D. W. Roper, M. W. S. E.: The author has struck the keynote where he states that one of the most important requisites in a large system is continuity of service. We spend a great deal of money, time, and energy in devising schemes which will enable us to give continuous service or to make the service more nearly continuous. Improvements in this line seem to have a cumulative effect, however. That is, the customers, once having appreciated a slight improvement in service, immediately feel called upon to ask for a further improvement, as we discovered in connection with lamp renewals some years ago. When customers had to call at our stations in person to get lamps renewed, we had comparatively few complaints. When, however, we began to deliver the lamps at their homes without any request from the customers, or without notice, we might say, we were immediately confronted with complaints because we would not take the old lamps out of the sockets. The same thing occurred in continuity of service. Some years ago customers accepted interruptions of a few minutes or hours; later, some of the large and important customers discovered that they could get duplicate service in some instances, and that by throwing a switch from one to the other in time of trouble they could have the service renewed in a very few minutes. Now they want an automatic switch to operate so that when trouble occurs it will cut out the damaged section without interrupting their service.

There appears to be a little difference of opinion on the subject of how quickly a switch should operate in order to open a damaged feeder. The paper states that it is the present general practice to have the switch open automatically after a sufficient interval of time has elapsed to permit any momentary surge to pass away. A similar scheme was once advocated for answering correspondence. The advocate of this scheme said that letters which caused disturbance in one's mental equilibrium should be laid aside until such mental surge had passed away. I am inclined to agree, however, with a later sentence in the paper, which states that the ideal relay and switch combination would be that which would instantly cut off a feeder suffering any defect. In the same paragraph some criticisms are made of the instantaneous relay. It is evident that the writer intends that these remarks should apply to instantaneous *overload* relays, because the descriptions of the Merz-Price system indicate that it is an instantaneous relay.

There is, however, still one other combination of instantaneous overload relays which is selective, and that scheme has been

in service for a number of years in the Interborough and Manhattan stations in New York. In that scheme, which is particularly applicable to a radial system as opposed to a ring system, the neutral of the generator is grounded through a resistance so designed that the maximum current which can flow to ground is approximately 1,000 amperes. The relays on the lines to the sub-stations are instantaneous relays and they have rather large sub-stations with four, five, and six or more lines from the same generating station to each sub-station. These lines are operated in multiple. The instantaneous relays are set for, say, 300% above the full load, so that in case of a short-circuit on one line the relay at the station on that line opens instantaneously, leaving it, of course, still connected at the other end. All of the four or five lines that are in multiple will feed current to that sub-station bus and then back on the damaged line through the short-circuit. This current, however, is limited by the neutral resistance so that dividing, as it does, between four or five lines, this current, which may be, say, 200 amperes, added to the normal current on each one of those lines, is insufficient to operate the relay except on the damaged feeder, which opens and leaves the other lines closed.

That selective method of operating relays applies only to cables which break down to ground and not to cables which break down between phases. The Merz-Price scheme is undoubtedly an excellent adaptation of a means to a particular end, and as one of the previous speakers has said, it is a scheme which is very nicely adapted to their system.

The paper indicates that the protective device is well adapted to the scheme used by the New York Edison Company. That scheme, however, while well adapted for use in New York, would not be so useful in this city. The description given in the paper indicates, although it does not set forth that fact specifically, that the cables must be insulated throughout their length, so that the capacity current due to an unbalance by fault in any one cable shall return over the lead of that particular cable. If the various transmission lines are all connected in various manholes for the purpose of prevention of damage by electrolysis, then that capacity current would return over all of those cables in multiple and no such device as that described here would operate.

Another objection to the Merz-Price scheme is that the number of current transformers required is double that used in this city in the radial scheme, where they are omitted in the sub-stations. The current transformer is one of the most vulnerable pieces of apparatus that we have on our system, and for that reason any increase in its number is something to be undertaken only after due consideration.

Still another point against the Merz-Price scheme is the fact, not mentioned by the author of the paper, that a case of trouble

on the pilot wire will also open the switch. The two current transformers at opposite ends of the pilot wire give an open circuit condition, so that if we ground the pilot wire at any place along its length we get the same effect as we will if we ground the conductor of the main cable; that is, we would open the circuit at both ends.

Our experience in this city shows that fully half of the troubles on transmission lines are due to external causes; that is, to picks driven by careless workmen, piles driven in by pile driver on track elevation, or work of that kind; to electrolysis or burnouts in other cables communicating through the ducts. If this same experience should be applied with the pilot wires, we would then expect that, so far as external interference is concerned, the number of cases of trouble on our transmission system would be double; so that if we could eliminate entirely the troubles from all other causes the total number of cases of trouble would still remain the same.

H. M. Wheeler, M. W. S. E.: In reference to the cost of conduit per single duct mile, mentioned in the paper, the experience that I have had would indicate that $500 per single duct mile is the minimum, and that $1,500 per single duct mile might be the maximum figure. This refers more particularly to Chicago conditions, where the cost of repaving more than doubles the cost of the conduit. I think the figures given in the paper are from one-tenth to one-fifth of what they should be.

Alfred Herz: With the two current transformers, the primaries of which are connected in series as would be the case in the Merz-Price system, and the secondaries connected in opposition, under what condition would those secondaries be? Would the voltage across the secondaries increase? Would the transformer have to be built to withstand excess pressure on the secondary side? In protecting the power transformers, the Merz-Price system proposes a third transformer; this third transformer is to be energized by two other current transformers. In a power transformer connected star-delta, that third transformer would not be in the neutral position, but would or could, according to my idea, change its voltage with change in load and therefore work any relay which would be connected to it with changing load.

Mr. Lyman: With the e. m. f. balancing, the voltage across the secondaries does increase, and that is one of the reasons why the ordinary current transformer is not well adapted to the balanced voltage system. In some cases non-inductive shunts are used across the secondaries.

In using the magnetic balance for power transformers having star-delta connections, the current transformers can either be connected inside the delta connection so as to obtain correct phase relations, or they can be connected in the lines with one set

of secondaries in star and the other in delta to give correct phase relation. With either method of connection there is no flux in the third transformer except under abnormal conditions produced by a ground or short, and consequently increasing load within reasonable limits is of no effect.

George H. Lukes, ASSOC. W. S. E.: We are greatly indebted to Mr. Lyman for his very interesting paper in which he has not only described standard American practice, but has given us valuable information regarding the Merz-Price system of protection. As Mr. Abbott has pointed out, our stations and substations are full of protective devices of one kind or another. These devices are costly and not only greatly increase the plant investment, but also result in higher operating expense. One or two of the author's illustrations are of great interest because they seem to show an inexpensive type of sub-station which might be well adapted for use in outlying districts where the business demands low investment and small operating expense. The fact that this type seems to be crude should not bar its adoption provided, of course, that it will do the work.

D. Bowman: I was impressed by the view of the substation, with the fewness of instruments in a great switchboard. Are the central station companies in England as careful as in our country about saving operating data of all kinds, taking various kinds of switchboard instruments?

Mr. Lyman: By referring to the chart, showing the character of the load that is furnished by the North East Coast Power Company, it will be noted that about 80% or 90% of it is for power for mining purposes. Great importance is laid on the reliability of service, but a variation in voltage of 5%, 2½% above or 2½% below, is allowed without complaint. In our large central lighting and power stations that would not be allowed. We must have not only absolutely reliable service but fine voltage regulation, and it is necessary for us to have voltage regulators and more instruments than are required in the case just mentioned. In other cases in England, in some of the large city lighting companies, for instance, more instruments are required.

H. C. Dean: I would ask if operators are dispensed with entirely in any of these stations, inspectors going around, say twice a day?

Mr. Lyman: Many of these stations are simply transformer stations and are locked up and left. If anything happens, substations being supplied by two sources of power it is not likely that more than one of them will fail and sometimes they are left for weeks without even being inspected. One of our American engineers recently spent several days inspecting this North East Coast Company's power distribution system, and stated that the operating force is never called out at night on account of trouble

occurring on the system, because it does not occur, probably, on more than one feeder going into a sub-station at a time. The report comes in and the next day the troubles that occurred during the night are adjusted.

Mr. Lukes: I want to ask Mr. Lyman if he has any information as to the use of this system on aerial transmission lines where the pilot cables would have to run on poles.

Mr. Lyman: I am told that it is used in a number of places in Germany, and on a large power distribution system in the Rand, in South Africa, on a good many overhead lines. The pilot cables are carried on a messenger wire in such cases. There is also some overhead wire in the North East Coast Power Company's system, though I believe the larger part of their transmission line is in underground cables. A French engineer stated, in a discussion which I recently read in an English paper, that in a section of an aluminum overhead transmission wire during a severe storm the conductors stretched and came together repeatedly. The operating force was obliged to get out and send men to the sub-stations to close the switches which were opened every few moments by the short-circuits that occurred by the swinging of these wires. No serious interruption to the power occurred, though this storm kept up for several hours.

Mr. A. Alsaker: The author states that the transformer sub-stations are left without operators. Apparently there must be, as I understand the term, in a transformer sub-station, a step from transmission voltage down to distribution voltage. Under those circumstances, where the sub-station is left without an operator, there can be only one distribution feeder or one low voltage feeder out of the sub-station, judging from the diagrams shown in the paper. Has this same system been applied to sub-stations having several distribution feeders, and can those sub-stations be left without attendants? If not, how are the distribution feeders protected in case there are several of them from the same sub-station?

Mr. Lyman: In this English distribution, many of the sub-stations that have no attendants supply power, as Mr. Alsaker has suggested, to some individual manufacturing concern. The outgoing low voltage feeders have relays set for very high overload or very large fuses, and some attendant has a key to the sub-station in case the secondary power is cut off. Of course, in this country we would be obliged in any case to use our own judgment as to the desirability of closing up a transformer sub-station. There are many transformer sub-stations that we all know of, which are normally kept closed, without an attendant.

H. B. Gear, M. W. S. E.: There is one point that might be a little further elaborated with regard to the range within which the Merz-Price system is specially applicable. The capacity of this station is given as 120,000 k. w. and the number of stations

about 150, so that the average size of these sub-stations is about 800 k. w., and the average full load capacity of the cables is from 3000 to 5000 k. w. It is, therefore, possible by this ring system to carry the load of four or five sub-stations, looping them together into one ring and feeding the entire load of the ring from one end in case either side goes out next to the power house. Of course, if any section in the middle of the ring goes out, the load will be divided in proportion to the amount carried on each side of the break. The only limit to the number of sub-stations on the ring is the amount of load that can be carried on the cable. With sub-stations averaging only 800 k. w. in size, several of them can be grouped on one ring and thus accomplish a considerable economy in the total lineal feet of cable required.

The conditions in American cities are different, however. The average size of sub-stations in Chicago is over 2000 k. w., and the same would be true of New York or any other large American city where railway and lighting service is given. There is no case in Chicago where more than two sub-stations could be grouped on one ring, and in most cases each station requires not only one cable but two, three, and in the case of some of the railway sub-stations as high as four or five cables, to carry the load. The radial system is, therefore, the only practicable one and is just as cheap as the ring system would be. The latter system could only be applied as an emergency supply for several sub-stations. Up to the point where the total load on the ring is less than the capacity of the cable, the ring system is economical and desirable. Beyond that point additional radial lines must be added in order to provide the additional capacity, and no further economy can be effected from a ring system of distribution, in which this form of protective device is especially applicable.

Mr. Junkersfeld: I would like to add just a few words to what the author and Mr. Gear have said regarding the condition on which the Merz-Price system is operated. In talking with Mr. Merz last summer, he stated that out of this large number of stations there are something like 100 that have less than 200 k. w. I call attention to the chart in the paper, which shows that only about 10% is lighting. Many of the plants have no automatic regulation; they supply load to collieries and manufacturing establishments of that sort. They also have some large sub-stations, such as we have in our large cities in this country, but more than two-thirds of these sub-stations are scattered through the country for isolated establishments. They have a wide diversity factor. As a matter of fact, their total coincident load, as I remember it, is something under 80,000 k. w., although their aggregate capacity is 120,000 k. w. That would bring the coincident load something under 500 k. w., but in order to bring up that 500 k. w. there are a fair number of large ones and a large number of quite small ones.

Closure.

The Author: The following paragraph from the paper will indicate, I think, that the writer did not intend to recommend this system for general and every class of work:

> "The considerable expense of the pilot cable will probably limit the use of the Merz-Price protective gear to heavy power circuits from power house to sub-stations of other sections of distributions; also for tie lines between power houses and tie lines between sub-stations, and especially where several sub-stations are supplied with power from the same feeder or feeders in ring connection. The writer also believes it a desirable protection for large turbine generators and large banks of transformers. He recommends the use of overload relays of the inverse-time-limit type on outgoing feeders from power house to sub-stations and on light and power circuits of sub-station apparatus."

It is not improbable that an overload relay can be operated from the same special current transformers that are used for operating the Merz-Price protective gear. I can see several ways of doing this. Whether some one of them would work out practically, I am not prepared to say, because I have made no experiments. I believe the device has merit for certain conditions where heavy power is transmitted comparatively short distances—that is, within a few miles—and where absolute reliability of service is required.

Referring to the remarks of Messrs. Schuchardt and Roper with reference to defects developing in the pilot cable, it is possible for defects to develop. It is possible for a workman to put a crowbar through a pilot cable just as he does through a power cable. One or two things can happen. If the pilot cable is injured in that way probably a short-circuit occurs between at least two of the pilot wires of the three wire pilot cable, so that as soon as the current on the power cable reaches half or three-quarters of its normal load, the oil switches at the end of the cable will open and cut out that piece of cable. But that does not shut down the sub-station. It does not offer any shock to the system. It does not do anything. It is only by the indication of instruments that the operator at either the sub-station or the power house knows that anything has happened. There are no strains put on the system at all and the cable is tested as soon as possible after it is automatically cut out. The power cable may be found to be in good operating condition. If so, then they look for trouble on the pilot cable and find, of course, that it has been short-circuited. It is possible for a conductor to separate through a defect in manufacture, but it would not be at all probable that all three conductors would open circuit in a cable at a given time, due to defects in manufacture.

It seems to the writer that the great advantage this protection

has over the protections that are now in general practice is that we can safely operate a large distribution system in parallel. We can operate the feeders going to a single sub-station in a large downtown district in parallel, the feeders always being in service, reducing to a minimum the line losses in those feeders, which may amount to considerable during the year. We also increase the reserve capacity of the circuits to that sub-station, because if any one of those units is cut out all of the other feeders being in multiple share equally the additional load, and I should say that the capacity might be increased from 5% to 15%—perhaps 40% to 50%, depending on the number of feeders.

We are so accustomed to the radial system that we do not perhaps appreciate that it is not the simplest system. As a matter of fact, it is not nearly so simple, it has not nearly the reserve capacity, and it has not the reliability for continuous service that a multiple system has. The multiple system is really exceedingly simple and we are not adding a great deal of apparatus to our system in adding this Merz-Price protective apparatus; we can probably cut out as much apparatus as we add, and then we have something that is ideally simple. It is perfectly possible to build current transformers insulated for five or six times the normal working pressure and we probably would never know that we had current transformers on the system were they built in such a way. That is the experience of Messrs. Merz and Price wherever the extra insulation has been provided. They are very particular about that, as well as the quality of both the main power cable and the pilot cable as Mr. Schuchardt said.

It is interesting to note that in the four years that this apparatus has been in service, the demand for apparatus in the last year has been as much as during the three preceding years. At the present time the orders for it are coming in rapidly from different parts of Europe, and one large power company in South Africa has been using it. There are some thirty to forty different companies with local distribution systems that have this system in operation and all those who have inspected it, as a number of our American engineers have, speak very highly of the protection that the apparatus gives.

As I have stated, there is the objectionable feature that for the protection of cables we are obliged to have this pilot cable, which we would all like to dispense with. The pilot cable perhaps is very largely compensated for by the additional reserve capacity in the other cable or in some cases by the cost of emergency cables which are put down at a great deal of expense and held as reserves. They are used only in case one of the main cables breaks down and the cost of putting those down would largely pay for the pilot cable together with the other slight expense.

G. A. Burnham (by letter): In connection with Mr. Lyman's paper on the protection of high tension power circuits and ap-

Condit Electrical Manufacturing Co.
Definite Time Limit Overload Relay

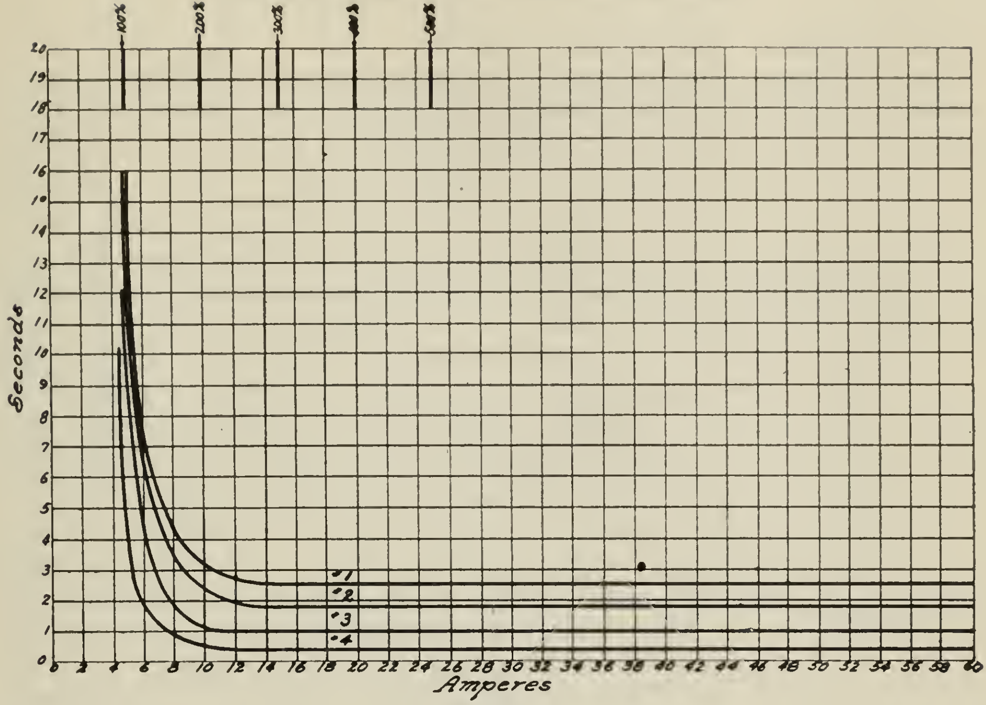


Fig. 10

Condit Electrical Manufacturing Co.
Definite Time Limit Overload Relay

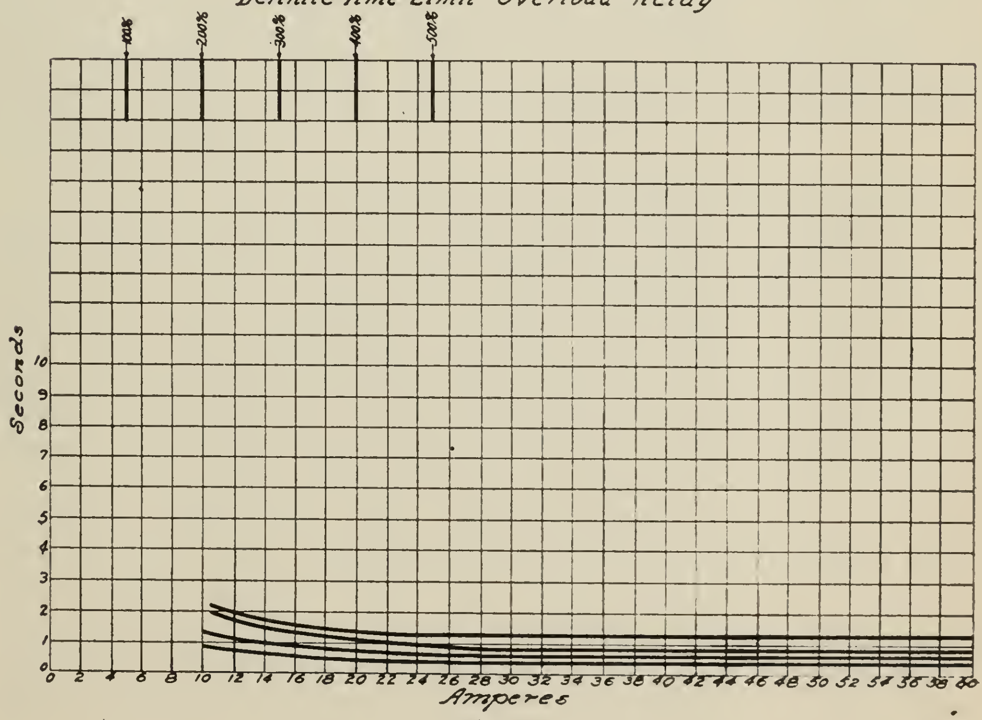


Fig. 11

paratus, I wish to state in connection with Fig. 3, which shows a curve of the time limit relay manufactured by the Condit Electrical Mfg. Co., that the curve shown is a special one, designed to meet a particular distribution system.

It is evident that this is not a good type of curve for the protection of a system where there is a liability of enormous energy on short-circuit conditions. The slope of the curve is very great, the curve becoming definite at approximately twice full-load current.

The curves shown in Figs. 10 and 11 are taken from exactly the same relay with different brush positions, showing the flexibility of this type of relay.

The character of the curve may be changed at will within certain limits, and for selective operation a curve of this character is desirable. If we wish to have only the proper switch open on heavy short-circuit conditions, the curves must never intersect, neither should they intersect the line representing zero time.

Another point in connection with relays for selective operation of circuit breakers is that they must be very accurate, and their settings must remain fixed. If the relay has an error of, say, 4%, this error must be taken into consideration when setting relays for selective action to insure their proper operation. This error serves to increase the maximum time necessary to give selective action and it is desirable to keep the maximum time on the definite part of the curve at its lowest possible value.

THAWING OUT WATER SERVICE PIPES BY ELECTRICITY

D. W. Roper, M. W. S. E.

There was no called meeting for February 26, 1912, but to the small company who gathered in the Society Rooms that stormy evening, Mr. Roper gave an informal talk on the work done by the Commonwealth Edison Company in thawing out the frozen service pipes throughout the city. The substance of these remarks has been written out by Mr. Roper and is here presented.

Although the Commonwealth Edison Company has never advertised this service, it has been thawing out water pipes with electricity for a number of years as an accommodation to customers. As the frost in the ground during the past few winters has not reached the water service pipes this particular branch of the business has languished. But this winter there has been a great revival.

Up to the first of January there had been no very cold weather, so that there was not more than about 18 in. of frost in the ground at that time. On account of the continued zero weather after the first of the year, the depth of frost in the ground rapidly increased, and by the middle of February the frost ranged between 5 and 6 ft. deep in the ground. As the water pipes are laid ordinarily at a depth of 4 to 5 ft., the result has been that a large number of water service pipes and a few water mains have been frozen.

The first calls for thawing out service pipes this winter came from a street where a trench had been opened in December during freezing weather, so that the earth was frozen when it was thrown out of the trench and could not be properly replaced when the trench was refilled. A few days later we had an inquiry from the city to learn whether we could thaw out water pipes, and as the city had never had any experience with this method they sent us a few trial orders. Finding the method entirely successful, orders began to come in more rapidly, and one gang was placed on this work in each of the three overhead districts. During the week ending February 10th orders were received at the rate of about 50 per day. During the first three days of the following week the orders averaged 150 per day, and, as we were thawing out only one-third of this number, arrangements were made with the city to increase the number of gangs on this work, and all of our own available men were transferred from construction and ordinary maintenance work to pipe thawing, and wagons and autos were transferred from other work to this service, so that by the end of the week we had a

total of eighteen gangs working on city pipe thawing jobs and were thawing out more than 100 service pipes each day!

The outfit used in this work is very simple. Previous experience had taught us that a supply of current at about 55 volts would thaw out most of the water service pipes in a few minutes and without injury to them or to the mains. As none of our transformers are connected for this pressure we arranged to reduce the pressure by connecting two transformers in series on the primary and in multiple on the secondary. These transformers can then be used without any regulating devices whatever, using the primary cutout as a main switch. As the visible supply of transformers decreased rapidly, the last few wagons fitted up for this work were equipped with a single transformer, the secondary connections being altered inside the transformer so as to deliver 55 or 110 volts. In a few cases 6 in. water mains have been frozen up, and these were thawed out by the application of 110 volts.

The amount of current which flows in the water service pipes ranges between 200 and 300 amperes, depending upon the length of the service pipe. The time required to start the water varies from five to fifteen minutes. In the case of the 6 in. water main a current of about 600 amperes thawed out the main in about one hour.

In thawing out the service pipes the owner of the building, or the city, has a plumber on hand who disconnects the service pipes from the house pipe at the building wall. One secondary wire is connected to the service pipe and the other to the nearest fire plug. When thawing out a street main the two secondary wires are connected to the fire plug at the two ends of the block where the main is frozen.

We have, to date, thawed out over 1,000 water service pipes, and the orders are still being received as fast as we can handle them. A curious feature in connection with the work occurred on Monday, February 19th. Sunday, the 18th, was the warmest day we had had in two months, the thermometer ranging above 50 degrees. A great many people who had been allowing their water to run theretofore in order to keep the pipes from freezing noted the thaw, and assumed that the cold weather was over. In fact, there was still 6 ft. of frost in the ground, and the thaw which we had on Sunday did not penetrate more than an inch or two into the ground. As a result we received about 50% more orders for thawing service pipes on the day following the thaw than we had received on any one day up to that time.

There have been a number of instances where service pipes have been thawed out a second time, and a smaller number where they have been thawed out three times. All of these orders have been received without any advertising whatever on the

part of the company and have been done rather as an accommodation to the property holders and to the city. The total, cost to the customers has averaged between $10.00 and $15.00 each, which is much lower than any other method of thawing out the pipes when they are frozen between the house and the street main. To dig up the ground and thaw out the pipes would have been considerably more expensive, and in addition it would make the pipes more vulnerable to the frost, as was shown by our first few cases, because the earth, having been removed in freezing weather, could not be properly replaced in the ditch, so that the frost would penetrate the loosely packed frozen ground in the trench far more quickly than it would through the solid ground.

IN MEMORIAM.

JEWETT N. DARLING, M. W. S. E.

Died April 22, 1911.

Jewett N. Darling was born in Charlton, Mass., in 1851, and spent his boyhood days on the farm. While a young man he entered Tufts College and graduated in Civil Engineering, afterwards taking a post-graduate course of Bachelor of Physics in 1880.

The following three years of his life were taken up in teaching in the preparatory school at Tufts and as Professor of Natural Science at Dean Academy, Franklin, Mass.

In 1883 he became associated with the engineering department of the West Shore and Buffalo Railroad Co. In 1885 he entered the employ of the Santa Fé System on the construction of the line to the Gulf through Indian Territory and Texas.

Two years afterwards he returned to the East and took up practice as a Consulting Engineer in Milford, Mass.

In 1892 he came to Chicago and was engaged as Engineer in Charge of Construction of the Burnside Machine Shops of the Illinois Central R. R. Co. under Mr. J. F. Wallace, then Chief Engineer.

Subsequently he was employed in charge of a party on the construction of the Northwestern Elevated Railroad in Chicago. In 1896 he returned to the Illinois Central R. R. Co. in Chicago, as assistant engineer in charge of location and construction of railroads in Mississippi, remaining in that capacity until 1903.

From 1904 to 1908 he was employed as assistant engineer in charge of reconstruction of the South Side Elevated Railroad, a work which required the skill of a master. The old line was practically reconstructed while traffic was kept up on schedule.

Mr. Darling was elected an active member of the Western Society of Engineers in 1901, and presented two papers before the society—one in 1902 on "The Yazoo Delta of Mississippi and Location and Construction of its Railroads"; and the other in 1908 on "Some Features of Construction of the South Side Elevated Railroad."

Mr. Darling was elected an Active Member of the Western tegrity, high in his ideals of professional ethics, and unswerving in his loyalty to his employers. He was successful in carrying a project through, and kind and considerate in dealing with his subordinates. His life work in the location and construction of railroads brought him face to face with many baffling obstacles, and in the Yażoo Delta he was surrounded by unusual difficulties, both as to unhealthfulness of the locality and hardships of the surroundings. These difficulties were overcome by the ability, care, persistency, precision, and ingenuity which characterized all of his labors.

During his engagement in the Yazoo Delta he contracted a serious case of malaria which probably resulted in shortening his life, and about two years ago he removed to Colton, California, with the hope of recovering his health, but without success. He died there April 22, 1911, and is survived by a widow, a son, and a daughter.

John P. Ball,
A. S. Baldwin,
Committee.

PROCEEDINGS OF THE SOCIETY.

Minutes of Meetings.

Regular Meeting, March 4, 1912.

A regular meeting of the Society (No. 777) was held Monday evening, March 4, 1912. The meeting was called to order at 8:15 p. m., President Armstrong presiding, with about 115 members and guests present. The minutes of the previous meetings were accepted unread.

The Secretary reported from the Board of Direction the election into membership of the following:

Leslie L. Perry, Chicago.................................Member
Elmer Juergens, Chicago...................................Member
Frederick F. Shafer, Springfield, Mo..........Associate Member

Also that applications for admission into the Society had been received from:

James S. Harvey, Jr., Chicago.
James Sorenson, Chicago.
Alden Bradford Whitney, Chicago—Transfer.
Sidney J. Robison, Chicago.
Frederick W. Greve, Jr., West Lafayette, Ind.
Floyd E. Downing, Chicago.
John A. Goetz, Arcola, Ill.
George M. A. Ilg, Chicago—Transfer.

William T. Walters, Chicago.
Frank H. Masters, Chicago.

There being no other business, the President introduced Mr. E. D. Dreyfus, of Pittsburg, who addressed the meeting on "New Developments in Steam Turbine Engineering." This was illustrated with a considerable number of lantern slide views.

Discussion followed from Messrs. Abbott, Almert, Junkersfeld, and the author.

Mr. Abbott moved a vote of thanks to Mr. Dreyfus, which was duly carried.

Meeting adjourned about 10:15 p. m.

Extra Meeting, March 11, 1912.

An extra meeting of the Society (No. 778)—a meeting of the Bridge and Structural Section—was held Monday evening, March 11, 1912.

The meeting was called to order at 8:25 p. m. by Mr. F. E. Davidson, chairman, with about 60 members and guests in attendance.

The subject for discussion announced by the chairman was "Light Compressive Members: (a) Economic Sections for Struts with High Ratio of $\frac{l}{r}$; (b) Portal Bracing." The discussion was opened by Mr. H. E. Horton and was continued by Messrs. Albert Smith, H. E. Vanderlip, J. Norman Jensen, H. J. Burt, W. L. Cowles, C. S. Pillsbury, O. H. Basquin, C. K. Mohler, F. G. Vent, L. McDonald, J. C. Blaylock, J. W. Bradford, and a closure from Mr. Horton, who, at the request of Mr. Davidson, presided as chairman the latter part of the evening.

Meeting adjourned at 9:50 p. m.

Extra Meeting, March 18, 1912.

An extra meeting of the Society (No. 779) was held Monday evening, March 18, 1912. President Armstrong called the meeting to order at 8:15 p. m., with about 100 members and guests in attendance. The President introduced Mr. W. H. Finley, a Past President of the Society, who read his paper on "Waterproofing of Engineering Structures." Discussion followed from the Chairman, and Messrs. C. B. Lewis, L. J. Hotchkiss, W. H. Lawrence, W. F. Steffens, F. E. Davidson, J. W. Pearl, W. F. Babcock, N. Malcolm and J. N. Canavan, with a closure from the author.

Meeting adjourned about 10:30 p. m.

J. H. Warder, Secretary.

BOOK REVIEWS.

History of Bridge Engineering. By Henry Grattan Tyrrell, C. E. Cloth; 6-in. x 9-in.; 480 pp.; 330 illustrations. Price, $4.00 postpaid. For sale by the author, Evanston, Ill.

Engineers have been charged with a neglect of the history of their profession and the works accomplished by engineers of former generations, and their interest in this line of research has been compared unfavorably with architects, who spend a great deal of their time in the study of the history of architecture. Russell Sturgis, in his dictionary of architecture, explains the difference in the attitude of engineers and architects towards constructional matters by stating that what belongs to methods discovered by precedent and proven to be safe and sound, lie within the province of the architect, thus leaving the engineer to deal with those parts varying in size according to their use and material, when precedent fails as a guide. The architect being the exponent of taste and beauty in construction, copies

what has been done, and in so copying also copies the methods of construction that support his beautiful facade. Since so much of his work is founded upon precedent, the study of the history of his art is essential. Lawyers are also a class of professional men to whom the study of the history of their profession is all important for the reason that law is supposed to be the crystallized common sense of many generations of men. That the engineer has neglected largely the historical side of construction work is due mostly to the fact that the scientific principles of construction have been changing with each generation and there has been so much to learn and unlearn in the time covered by the span of the life of the ordinary engineer, that many engineers believe their time is wasted in stopping to look over the records of former engineers famous in their day.

Surgeons do not need to study the history of surgery and trace step by step the advances made in each generation since men commenced to study the human body; but they do it nevertheless, if for no other reason than to read the chronicle of their profession and its masters; to experience wonder at the advances made at times and the utter loss at times of the gains made, the reasons for which are not always apparent by the study of contemporary events. Engineers need to study the history of their profession for the same reasons that impel surgeons and men of science generally to study the history of science and its applications; for only a knowledge of what has been done before will keep a man from wandering far afield at times when the investigative instinct seizes hold on him. The records of the patent office show that year after year men come forward to patent things which they believe to be original inventions, only to find that many years before patents had been granted for these identical things. Engineers daily re-invent devices and methods and all designers spend considerable time, often wasting much of their time, devising methods for doing things when better devices for the same work were perfected years before, but their unfortunate habit of despising old things engendered inefficiency.

In giving the profession a history of bridge building, Mr. Tyrrell has performed a needed task and performed it well. The book is written in an interesting style and is well illustrated. The young engineer should by all means possess the book and learn something of the bridge building business other than the calculation of stresses and the detailing of modern structures. The reviewer regrets that the author did not give in his book, by foot-notes or by a chapter of biliography, his sources of information. In his book it is of course impossible to go closely into particulars as to the details of design. To have done this would have made the book rather heavy reading, instead of the easily read book it is. Many readers, however, would appreciate a guide to sources of information in order that studies may be made of details. When another edition is printed it is hoped the author will make this addition. The book should form a part of the course in bridge engineering in all technical schools and should be on the shelf of all engineers.

E. M.

The Elements of Structures. Prepared in the Extension Division of the University of Wisconsin by George A. Hool, S. B., Assistant Professor of Structural Engineering, The University of Wisconsin. McGraw-Hill Book Co., New York and London; cloth; 6 by 9 in.; pp. 188; about 200 illustrations in text. Price, $1.75, net. This may also be obtained for the same price in nine assignment pamphlets, with loose-leaf binder.

For several years the University of Wisconsin has been giving correspondence courses, following the example of the University of Chicago, and with marked success. The greatest difficulty encountered was the securing of suitable texts, so the instructors have been using mimeographed sheets, making corrections from time to time, until now the publication of

a series of Extension Texts has been begun, the book under review being the first.

This work is sold in regular text-book form and also in form to use with correspondence instruction. The style is clear and partakes somewhat of the lecture method. The work is intended for students who have had the usual common and high school training in arithmetic, algebra, plane and solid geometry, logarithms, trigonometery, mechanical drawing, and strength of materials. It treats only of general methods to be followed in design. It is exceedingly good and so far as it goes might be a handy work of reference for a man who is employed in the office of an engineer or architect and is anxious to "learn more so he can earn more". For such a man the reviewer would recommend first the study of "Bridge and Structural Design" by Thompson, followed by the book under review. He should then be ready to take up "Theory of Structures" by Spofford, and follow with "Simple Steel Structures" by Morris, the only book extant that deals with detailing in a proper manner. The resident student has the advantage of being able to get hold of his professor frequently, or can obtain help from some of the other students, so from one book he can frequently acquire all needed information relating to a certain subject. The self-tutored man, however, always requires several books at his elbow, so he may obtain from one, information not properly presented in another. This book under review is hardly a book for self-tutored men without being accompanied with others. It is like a large number of books now being poured out on the market; partial texts written to fill a definite place in a course of instruction in a certain school and hardly available for use in other institutions or for individuals not taking the complete course.

E. McC.

LIBRARY NOTES.

The Library Committee desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

H. M. Lane, Cleveland, Ohio:
- The Core Room, Its Equipment and Management. Pam.

H. M. Byllesby & Co.:
- The Colorado Springs Lighting Controversy. Cloth.
- Alabama State Agriculture Department, Bulletin No. 27. Pam.
- Municipal Public Service Industries, A. P. Foote. Cloth.
- Brown's Directory of American Gas Companies, 1909-1910. Two vols. Cloth.

E. E. R. Tratman, M. W. S. E.:
- New Hampshire Highways, U. S. Dept. of Agriculture. Pam.
- Mileage and Cost of Public Roads in the United States. Pam.
- Wisconsin Engineer, February, 1912. Pam.

H. G. Tyrrell, Chicago:
- History of Bridge Engineering, Tyrrell. Cloth.

The Macmillan Co.:
- Who's Who in Science, 1912. Cloth.
- A Laboratory Manual of Physics and Applied Electricity, Nichols & Blaker. Cloth.

McGraw-Hill Book Co.:
- The Elements of Structures, Geo. A. Hool. Cloth.
- Standard Forms of Field Notes for Civil Engineers, Anthony.

M. G. Lloyd, Chicago:
  Langley Memoir on Mechanical Flight. Paper.

McGraw Publishing Co.:
  Electric Railway Directory, February, 1912.

GOVERNMENT PUBLICATIONS.

United States Department of Agriculture:
  Development of Methods of Draining Irrigated Lands. Pam.
  Report on the Belzoni Drainage District in Washington County, Miss. Pam.
  Report on the Black Swamp and Jacob Swamp District, N. C. Pam.

United States Geological Survey:
  The Production of Spelter in the United States in 1911. Pam.

United States Coast and Geodetic Survey:
  Report of Superintendent, 1911. Cloth.

Interstate Commerce Commission:
  Twenty-fifth Annual Report, 1911. Cloth.
  Second Annual Report of Statistics of Express Companies, 1910.

EXCHANGES.

American Society for Testing Materials:
  Proceedings, 1911. Paper.

Association of Transportation and Car Accounting Officers:
  Proceedings, December, 1911. Pam .

American Society of Civil Engineers:
  Year Book, 1912. Cloth.

American Society of Mechanical Engineers:
  Year Book, 1912. Cloth.

Michigan State Board of Health:
  Thirty-eighth Annual Report, 1910. Cloth.

Boston Transit Commission:
  Seventeenth Annual Report, 1911. Cloth.

Liverpool Engineering Society:
  Transactions, Vol. 32, 1911. Pam.

Connecticut Railroad Commission:
  Annual Report, 1911. Cloth.

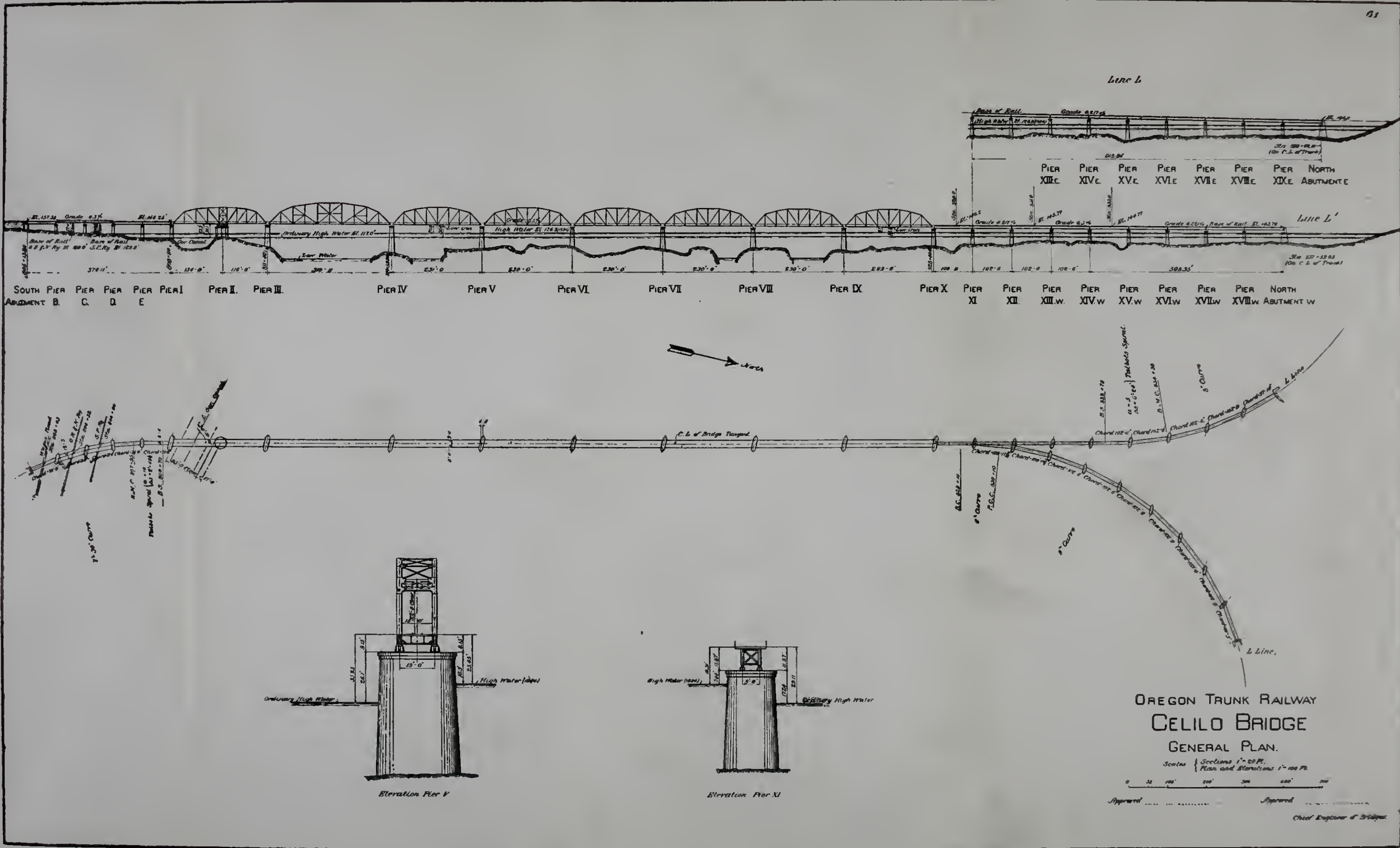
MEMBERSHIP.

Additions.

Juergens, Elmer, Chicago.......................................Member
Perry, L. L., Chicago.......................................Member
Shafer, Frederick F., Springfield, Mo.....................Associate Member

Deaths.

Harris, Wm. H., Chicago.................................January 31, 1912
Metcalf, John S., Chicago.................................March 4, 1912


Line L
Pier XIII E
Pier XIV E
Pier XV E
Pier XVI E
Pier XVII E
Pier XVIII E
Pier XIX E
North Abutment E
Line L'
South Abutment
Pier B
Pier C
Pier D
Pier E
Pier I
Pier II
Pier III
Pier IV
Pier V
Pier VI
Pier VII
Pier VIII
Pier IX
Pier X
Pier XI
Pier XII
Pier XIII W
Pier XIV W
Pier XV W
Pier XVI W
Pier XVII W
Pier XVIII W
North Abutment W
L Line
Elevation Pier V
Elevation Pier XI
Oregon Trunk Railway
Celilo Bridge
General Plan.

2

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Plate II

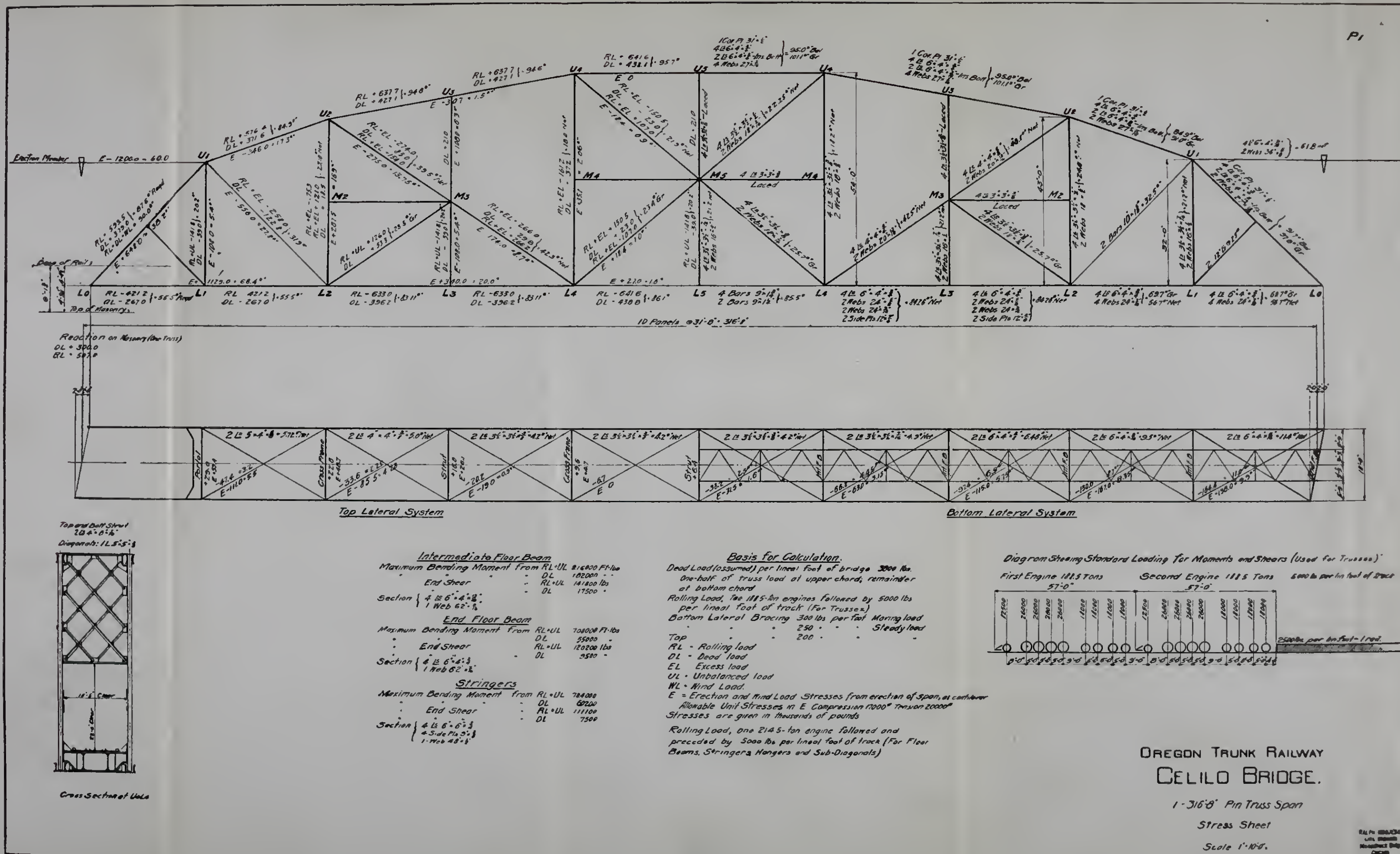


PLATE II

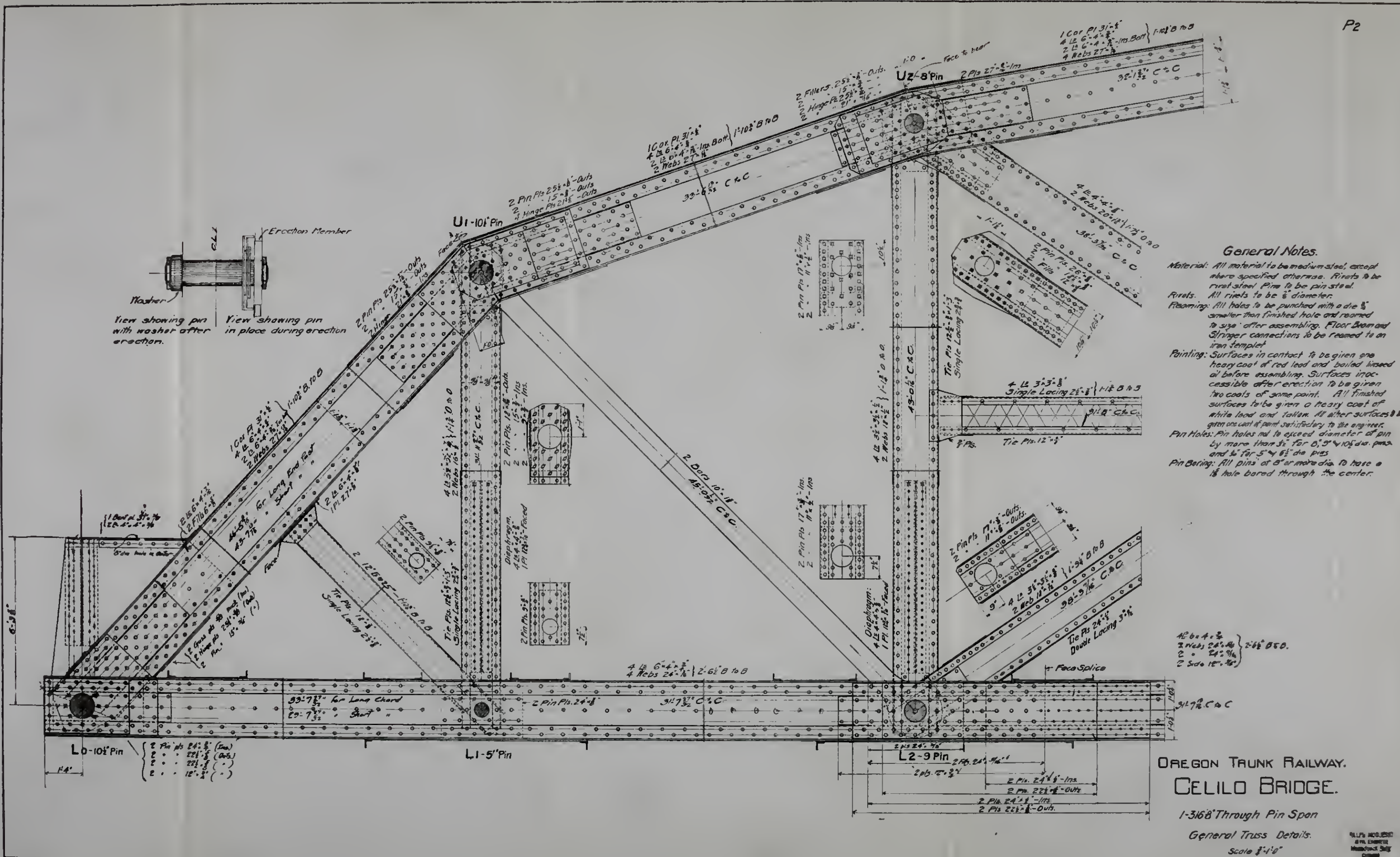

P2
U1-10½" Pin
U2-8" Pin
L0-10½" Pin
L1-5" Pin
L2-9 Pin
Erection Member
Washer
View showing pin with washer after erection.
View showing pin in place during erection
General Notes.
Material: All material to be medium steel, except where specified otherwise. Rivets to be rivet steel. Pins to be pin steel.
Rivets. All rivets to be ⅞" diameter.
Reaming: All holes to be punched with a die ⅛" smaller than finished hole and reamed to size after assembling. Floor Beam and Stringer connections to be reamed to an iron templet.
Painting: Surfaces in contact to be given one heavy coat of red lead and boiled linseed oil before assembling. Surfaces inaccessible after erection to be given two coats of same paint. All finished surfaces to be given a heavy coat of white lead and tallow. All other surfaces to be given one coat of paint satisfactory to the engineer.
Pin Holes: Pin holes not to exceed diameter of pin by more than 1/32" for 8", 9" & 10½" dia. pins and 1/50" for 5" & 6½" dia. pins
Pin Boring: All pins of 8" or more dia. to have a 1½" hole bored through the center.
Oregon Trunk Railway.
Celilo Bridge.
1-316'8" Through Pin Span
General Truss Details.
Scale ⅜"=1'0"

Plate IV

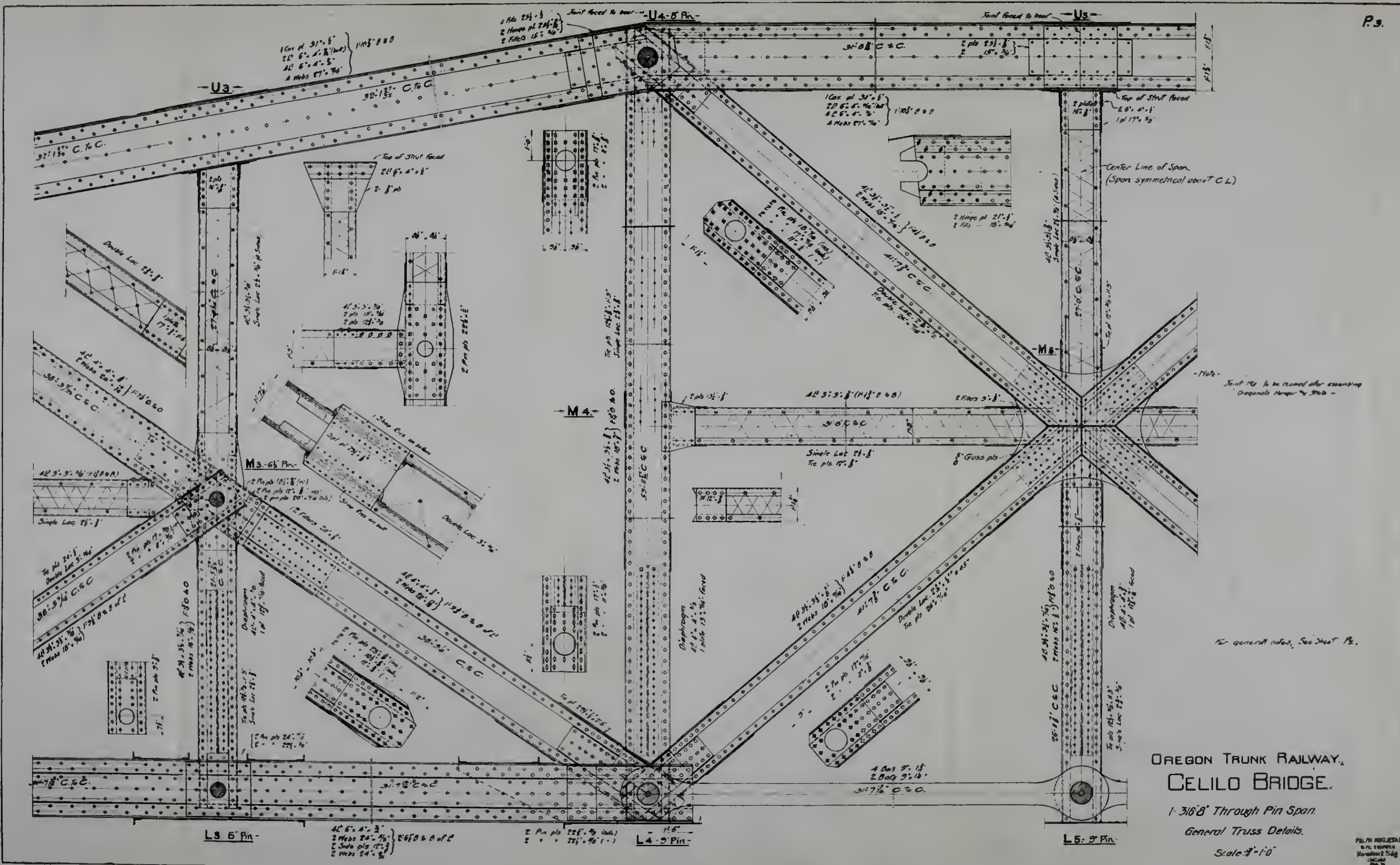


PLATE IV

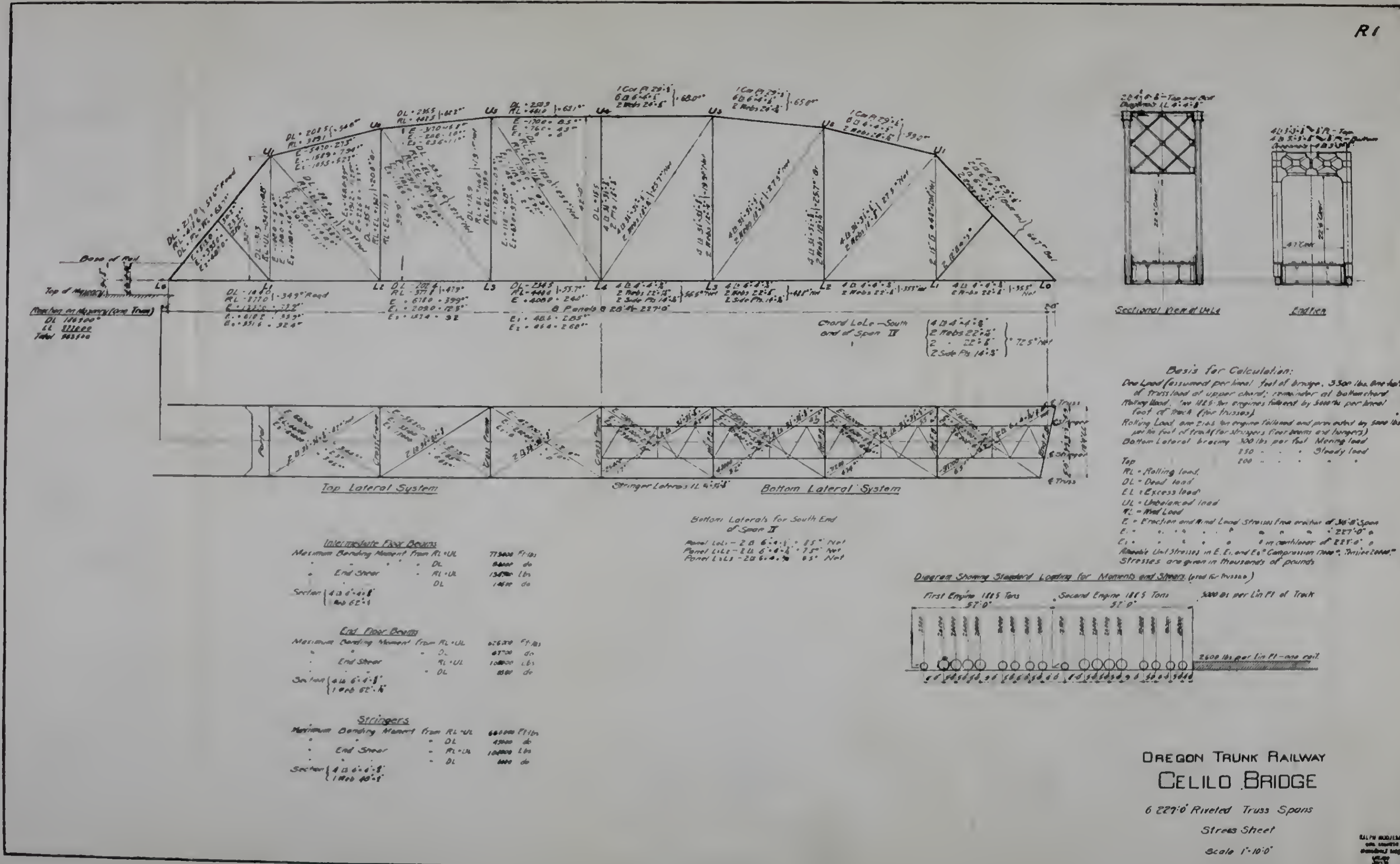

R1
Top Lateral System
Bottom Lateral System
Sectional View at U4L4
End View
Basis for Calculation:
Intermediate Floor Beams
End Floor Beams
Stringers
OREGON TRUNK RAILWAY
CELILO BRIDGE
6 227'-0" Riveted Truss Spans
Stress Sheet
Scale 1" = 10'-0"

PLATE V

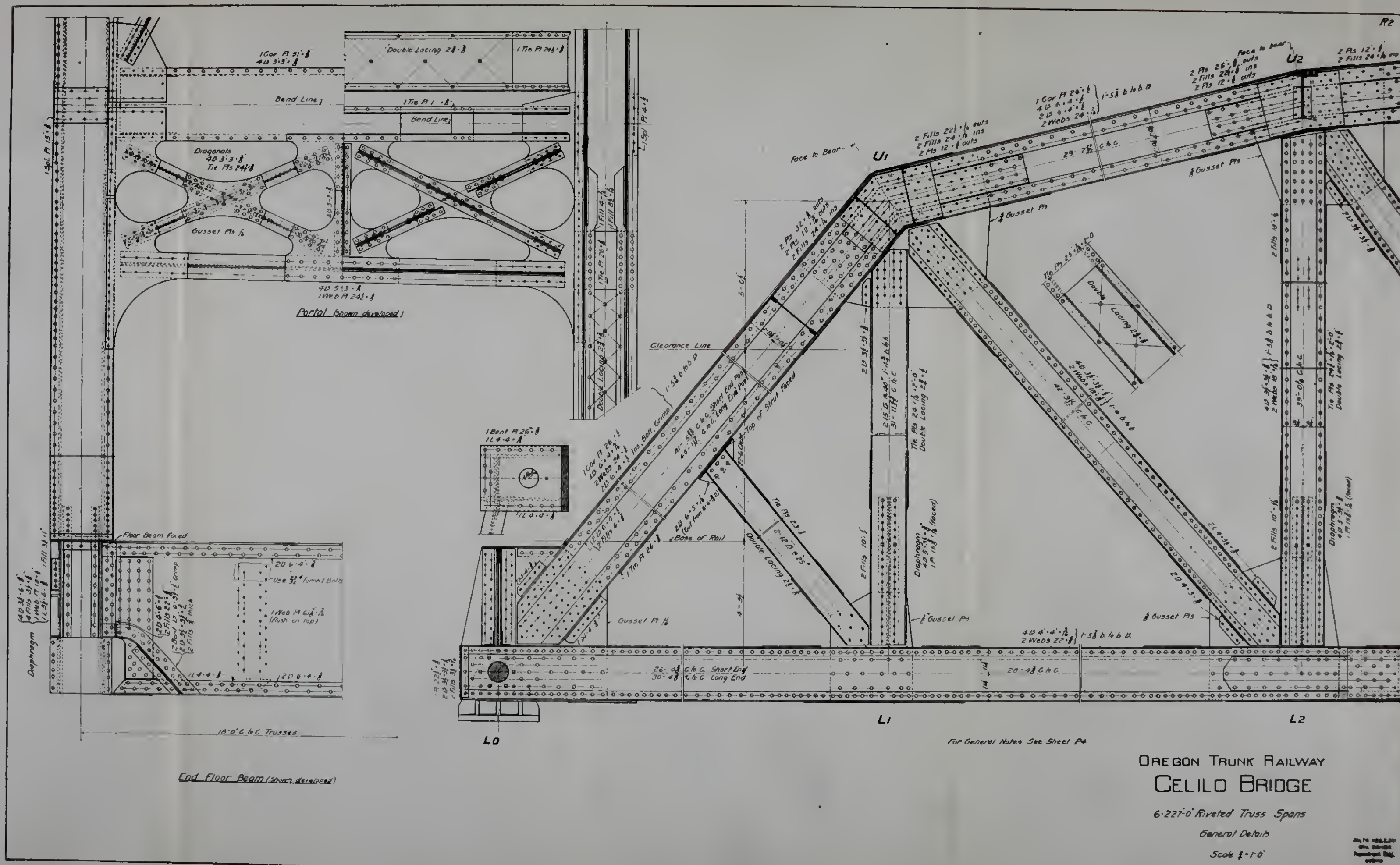

Portal (Shown developed)
End Floor Beam (Shown developed)
Oregon Trunk Railway
Celilo Bridge
6-227'-0" Riveted Truss Spans
General Details
For General Notes See Sheet P4

PLATE VI

Plate VII

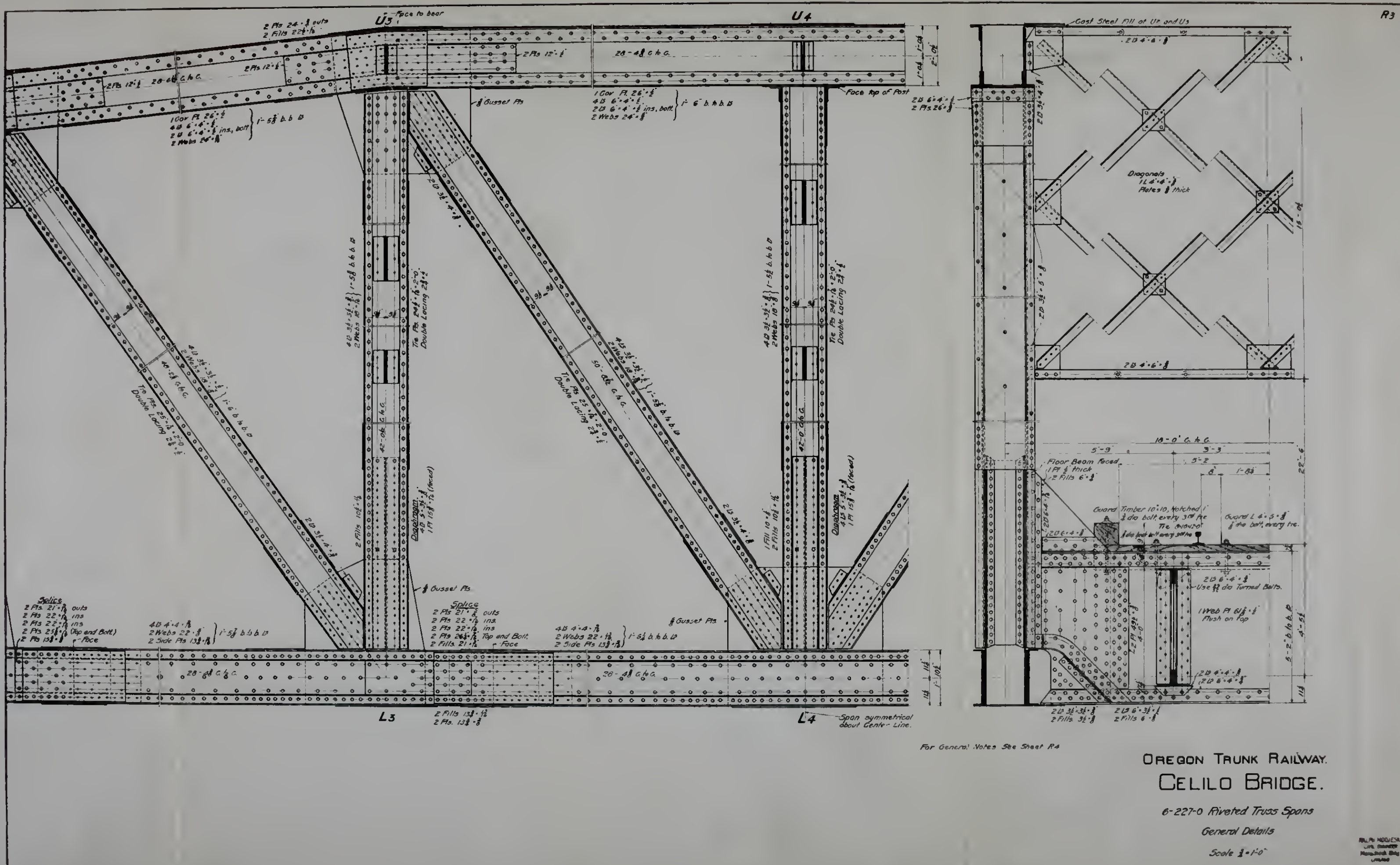


PLATE VII

Plate VIII

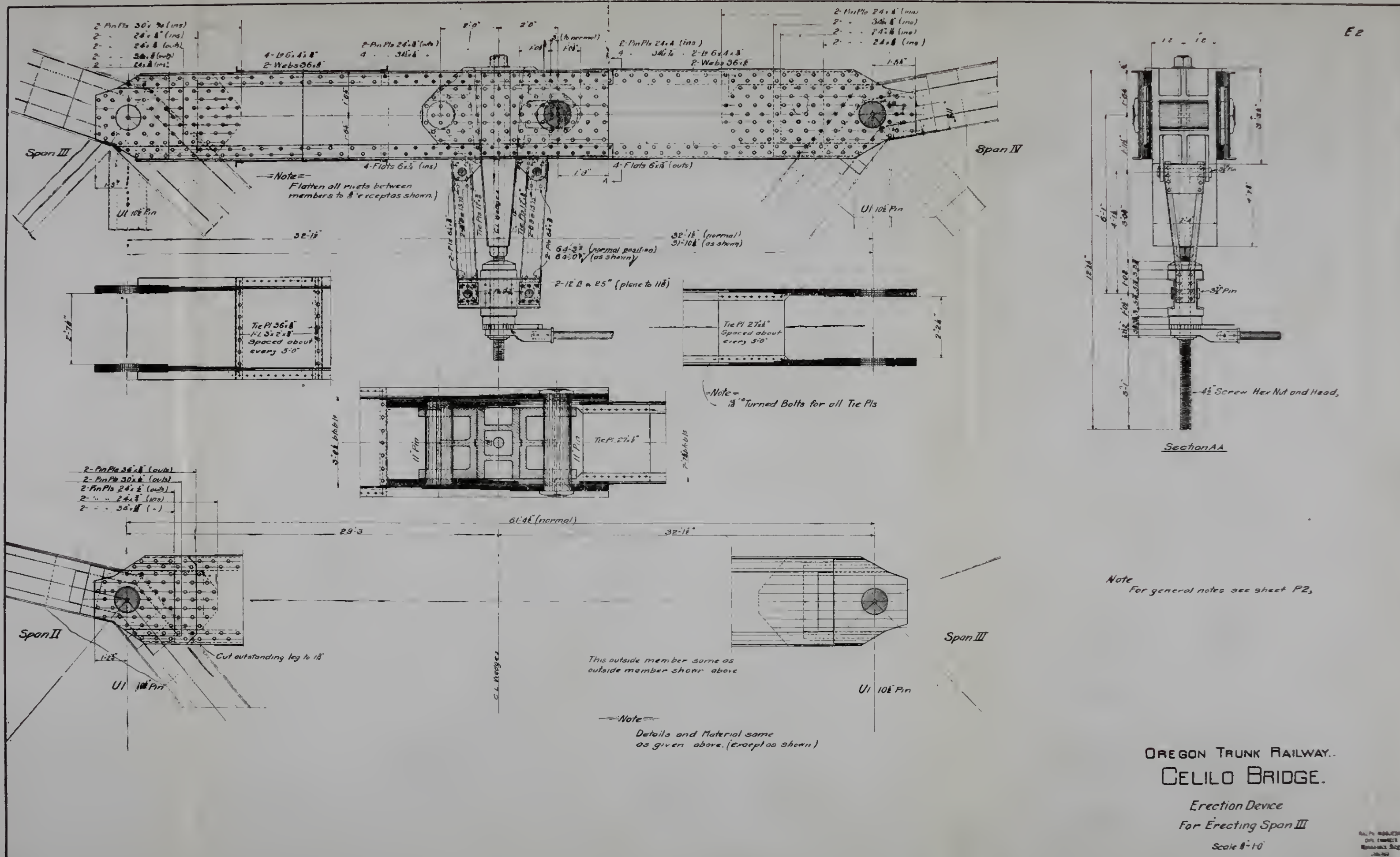
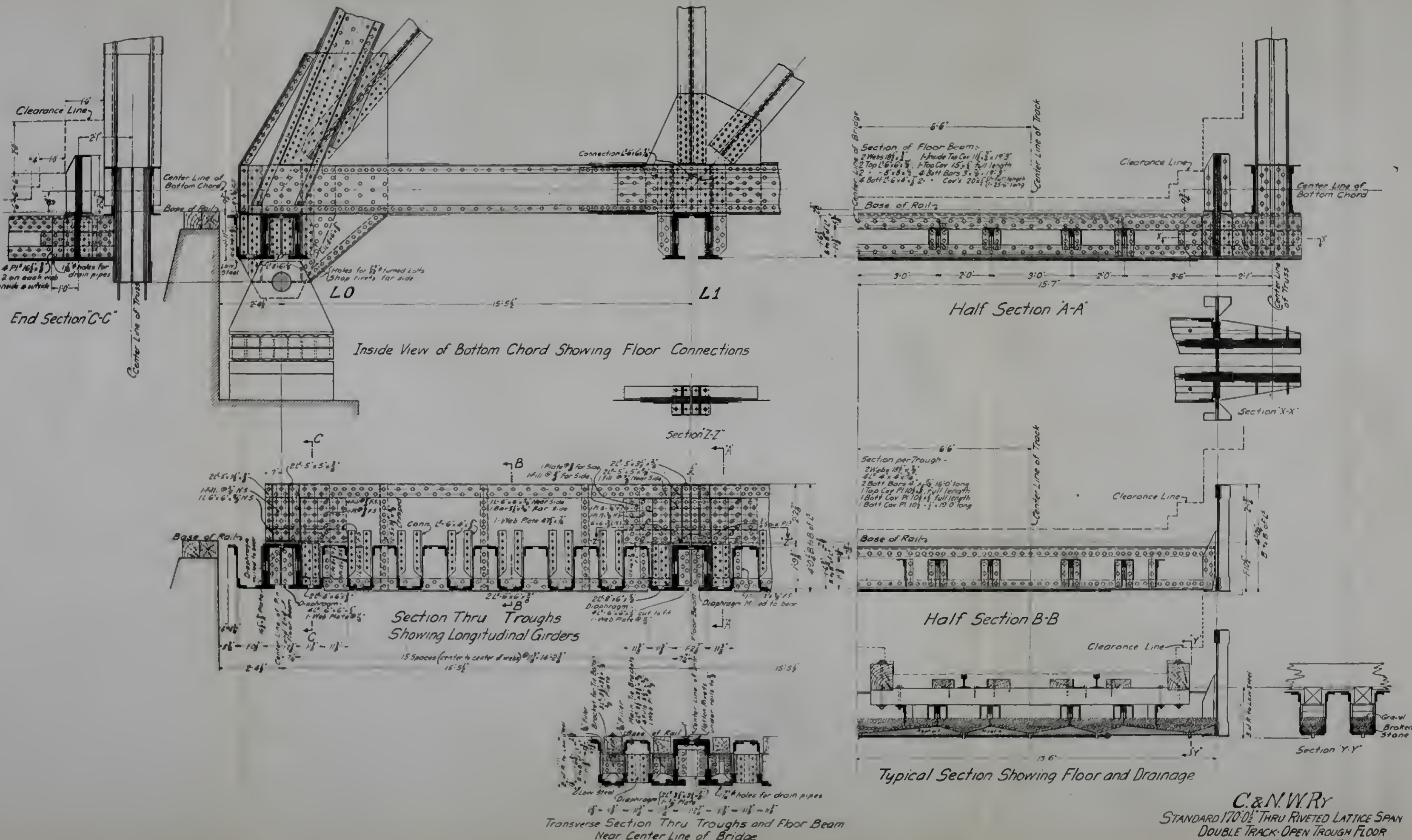


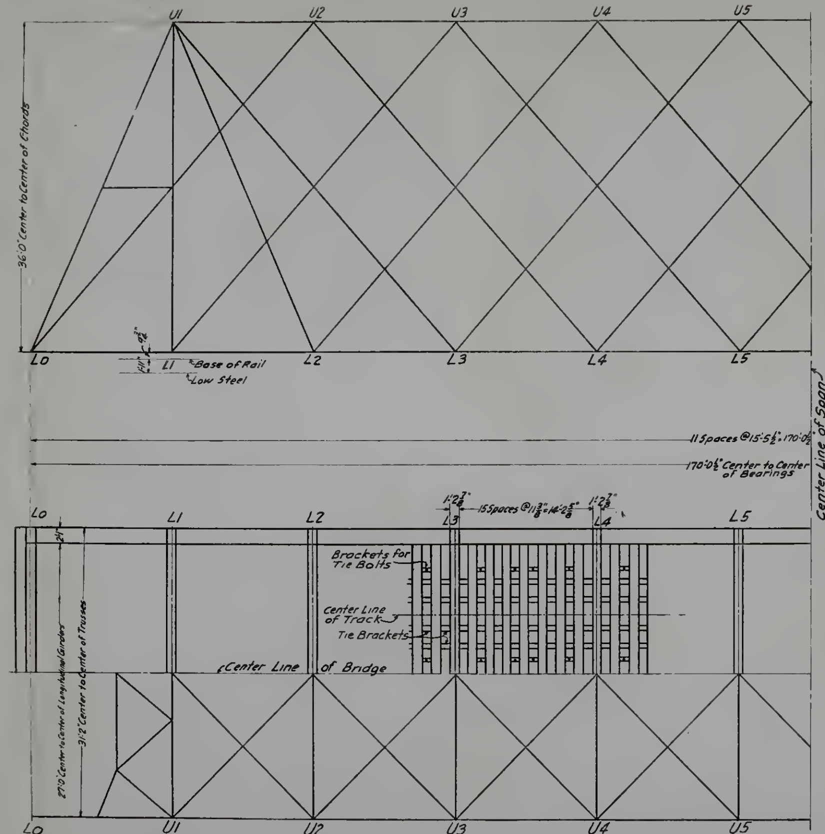
PLATE VIII

PLATE IX.



C.&N.W.Ry
STANDARD 170'-0½" THRU RIVETED LATTICE SPAN
DOUBLE TRACK-OPEN TROUGH FLOOR
GENERAL DETAILS OF FLOOR

PLATE X.



FLOOR SYSTEM

LONGITUDINAL GIRDER	END SHEAR	FLANGE STRESS
Section of Top Flange { 1 L 6"×6"×⅜" = 4.36; 1 Bars ½"×¾" = 4.13; ⅛ Web 47½"×7/16" = 2.60; 11.09 Section of Bott. Flange { 2 Ls 6"×6"×⅜" = 7.97; ⅛ Web 48"×7/16" = 2.63; 10.60□" N	D.L 15.0 L.L 103.0 I 62.0 180.0÷9 = 20.0□" Gr	D.L 15.5 L.L. 88.3 I 56.2 160.0 – 15 = 10.67□" Net
END FLOOR BEAM 2 WEBS ACTING	**END SHEAR**	**SECTION MODULUS REQD**
2 Webs 18½"×11/16" 2 Top Ls 6"×6"×11/16" 2 Top Ls 8"×8"×½" 4 Bot Ls 6"×4"×11/16" 1 Top Cov Pl 15"×⅝" (Full Length) 2 Bot Cov Pls 20"×½" (1 Full Length, 1-18'6" long) Sec. Mod = 562	D.L. 23.0 L.L. 103.0 I 63.0 189.0÷9 = 21.0□" Gr	D.L 74.3 L.L 303.0 I 182.7 560.0
INTERMEDIATE FLOOR BEAM 2 WEBS ACTING	**END SHEAR**	**SECTION MODULUS REQD**
2 Web Pls 18½"×¾" 2 Top Ls 6"×6"×7/8" 2 Top Ls 8"×8"×½" 4 Bot Ls 6"×4"×⅞" 1 Inside Top Cov Pl 11½"×¾"×19'3" 1 Top Cov Pl 15"×½" (Full Length) 4 Bot. Bars 3"×⅞"×19'3" lg. 2 Bot Cov Pls 20"×½" (Full Length, 23'6" long) Sec. Mod. = 708	D.L. 42.0 L.L 140.0 I 81.0 263.0÷9 = 29.22□" Gr.	D.L. 125.0 L.L. 372.0 I 208.0 705.0
INTERMEDIATE TROUGH 2 WEBS ACTING	**END SHEAR**	**SECTION MODULUS REQD**
2 Webs 18½"×⅜" 4 Ls 4"×4"×¾" 2 Bot. Bars 4"×⅝"×16'0" lg. 1 Top Cov. Pl. 10½"×⅝" Full Length 1 Bot. Cov. Pl. 10½"×½" Full Length 1 Bot Cov. Pl 10½"×½"×19'0" lg. Sec. Mod. = 299	D.L 4.0 L.L. 30.0 I 20.0 54.0÷9 = 6.0□" Gr.	D.L. 21.6 L.L. 168.0 I 111.6 301.2

GENERAL NOTES

Loading:-

Live Load:

For Trusses, Longitudinal Girders and Floor Beams - Coopers Class E50.

Impact $I = \frac{3}{4} L \times \frac{L}{L+D}$ where I = Impact
L = Live Load
D = Dead Load

For Intermediate Troughs, 30,000# on each rail assumed to be distributed over two ties.

Dead Load:-

Trough Floor = 155# per sq. ft.
Each Truss = 4570# per lineal ft.

Stresses are given in thousands of pounds.

+ Indicates Compression and – indicates Tension

Unit Stresses:-

Tension for structural steel, 15000# per sq. inch.

Compression for structural steel:-

$$P = \frac{15000}{1 + \frac{L^2}{13500 r^2}}$$ where:-

P = Permissible working stress per sq. inch.
L = Length of member in inches
r = Least radius of gyration in inches

Bending:- For Pins 22000# per sq. inch.

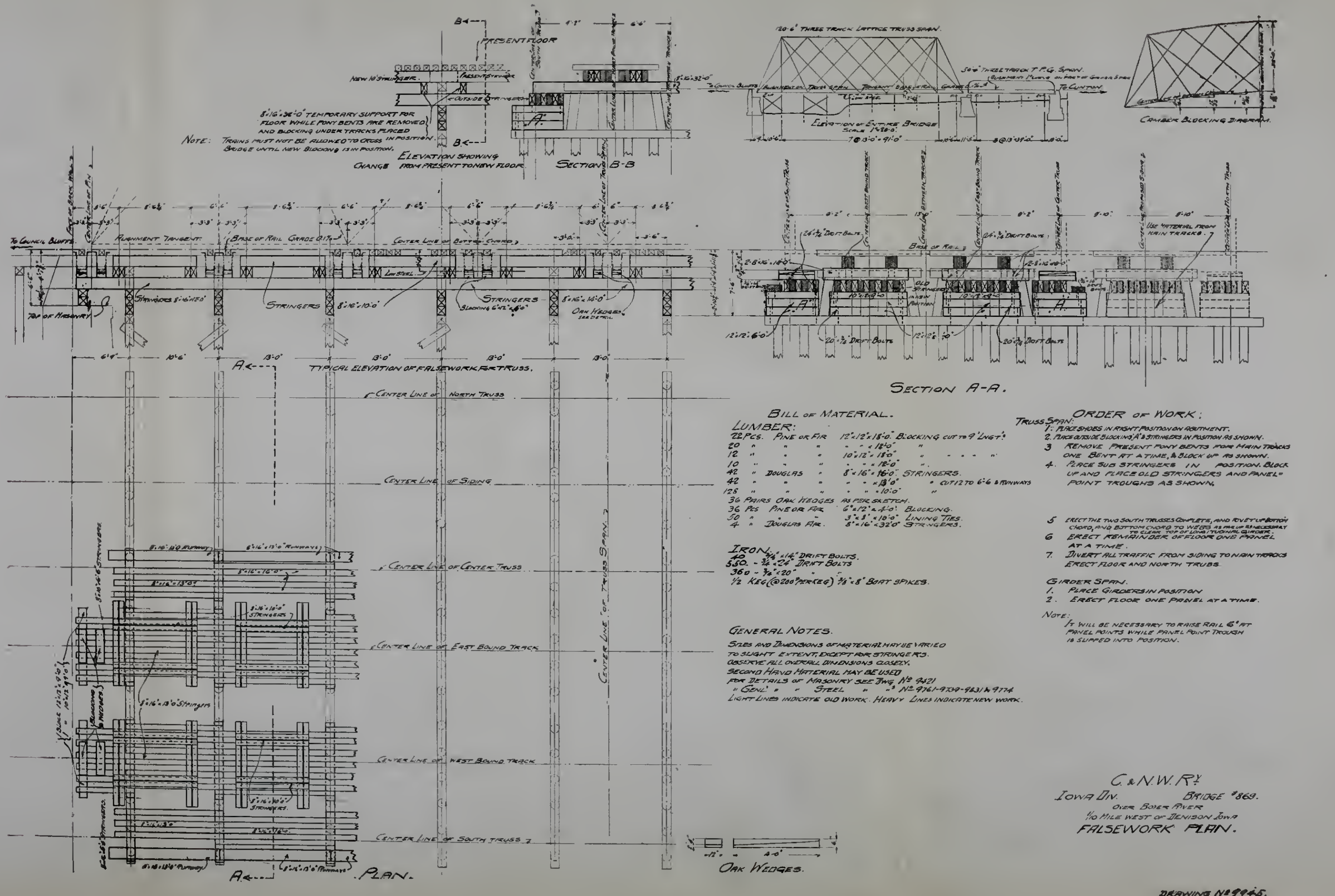
Bearing:- For Pins and Shop Rivets, 22000# per sq. inch
For Field Rivets, 17600# per sq. inch.

Shearing:- For Pins and Rivets, One half of Bearing Values
For Web Plates 9000# per sq. inch

C. & N. W. Ry.
STANDARD 170'0½" THRU. RIVETED LATTICE SPAN
DOUBLE TRACK - OPEN TROUGH FLOOR
GENERAL PLAN

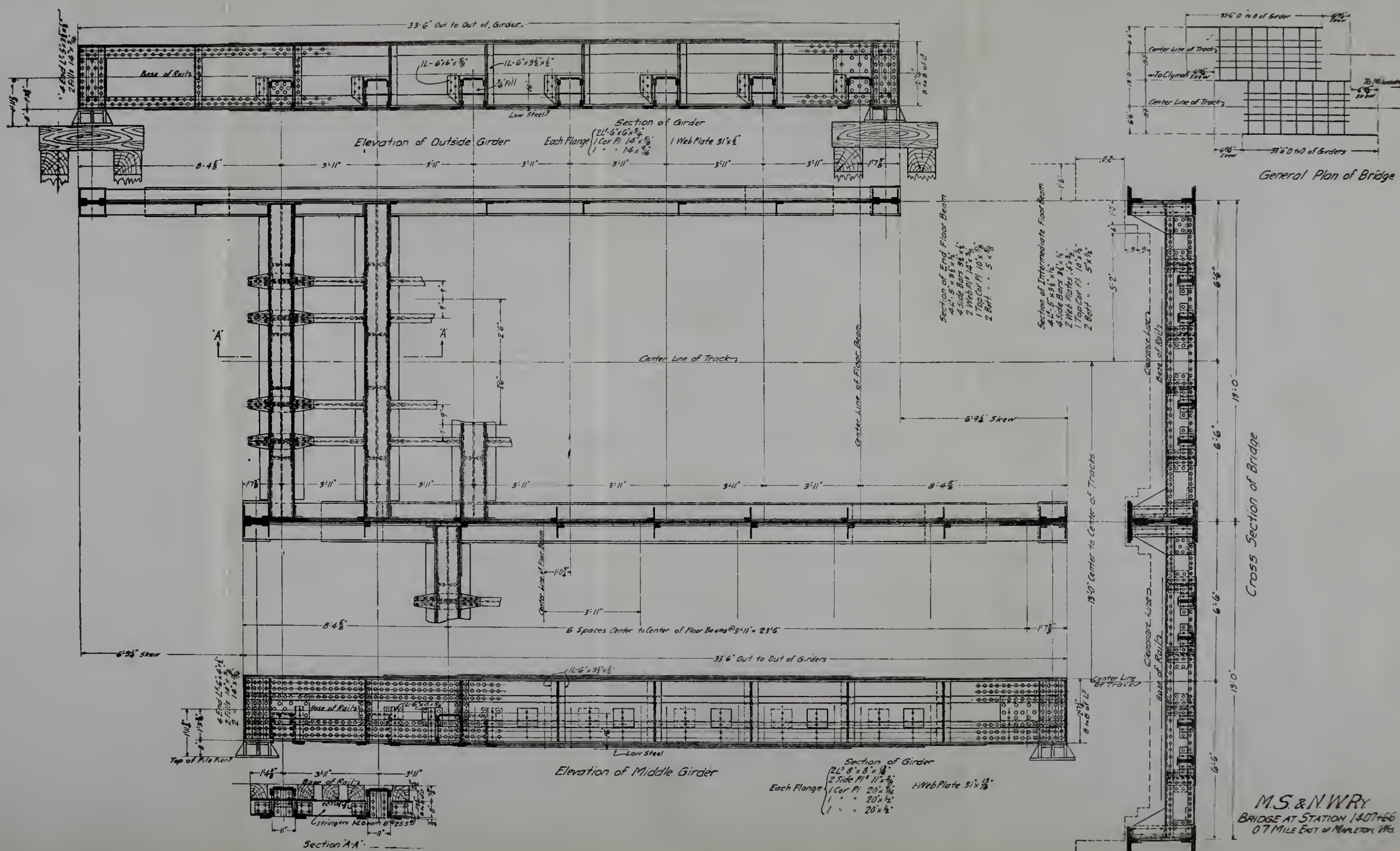
Western Society of Engineers
Vol. XVII. No. 3. March, 1912
Dalstrom—Shallow Floors for R. R. Bridges.

PLATE XI.



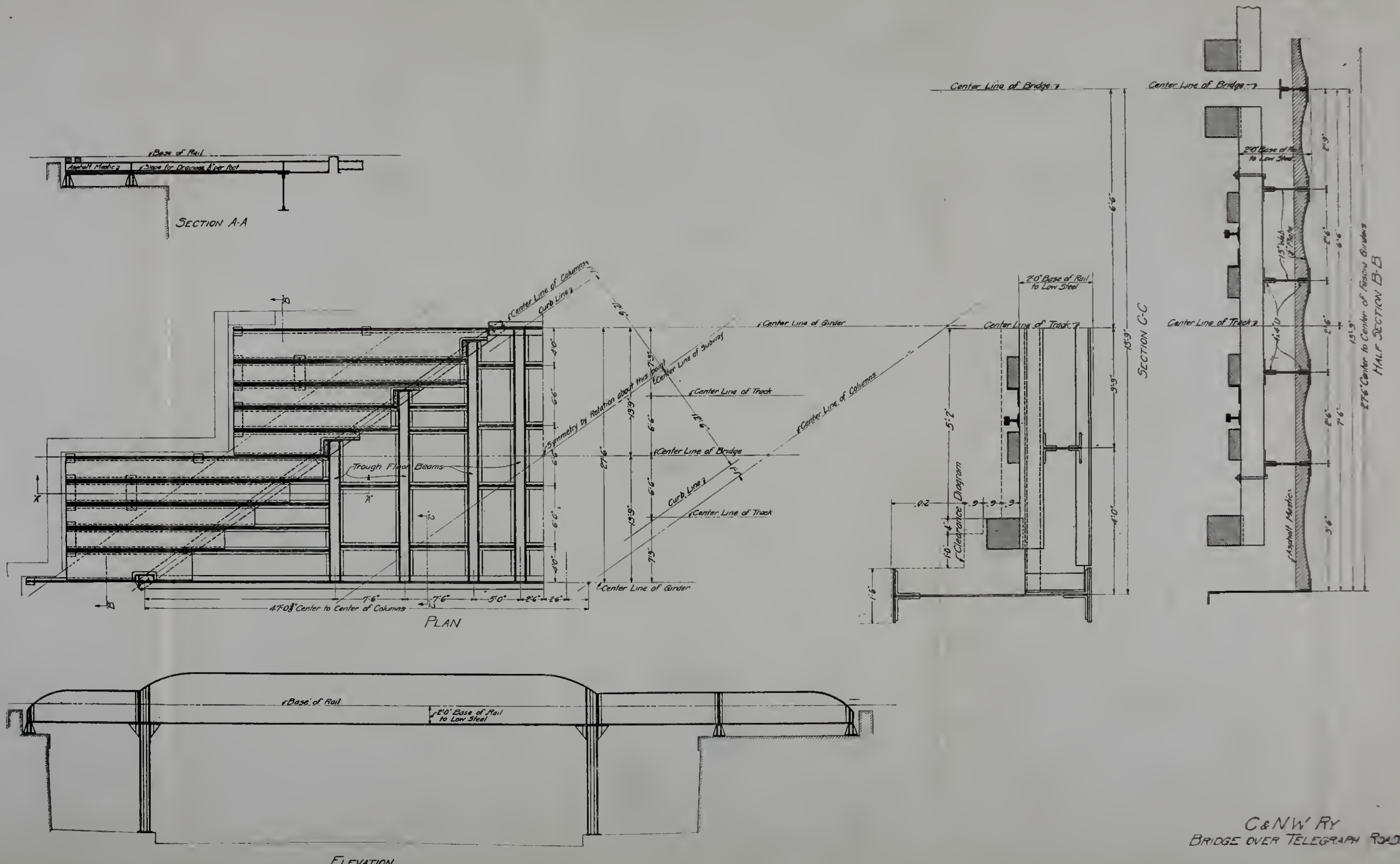
Western Society of Engineers
Vol. XVII. No. 3. March, 1912
Dalstrom—Shallow Floors
for R. R. Bridges.

PLATE XII.



WESTERN SOCIETY OF ENGINEERS
Vol. XVII. No. 3. MARCH, 1912
Dalstrom—Shallow Floors for R. R. Bridges.

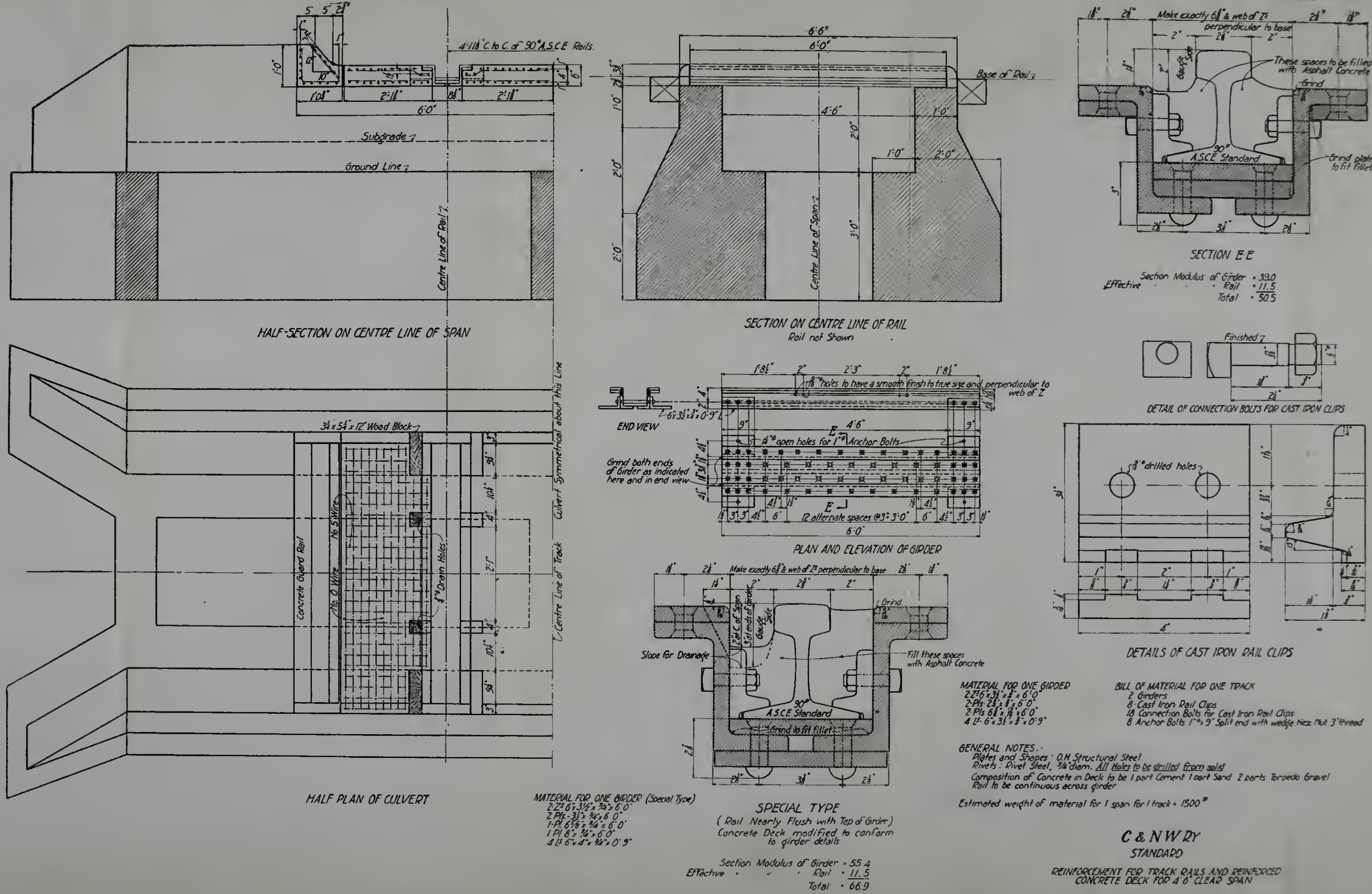
PLATE XIII.



C&NW RY
BRIDGE OVER TELEGRAPH ROAD

WESTERN SOCIETY OF ENGINEERS
Vol. XVII. No. 3. MARCH, 1912
Dalstrom—Shallow Floors for R. R. Bridges.

PLATE XIV.



Journal of the

Western Society of Engineers

VOL. XVII APRIL, 1912 No. 4

CHICAGO'S WATERWAYS IN THEIR RELATION TO TRANSPORTATION

LIEUT.-COL. GEORGE A. ZINN.*

Presented Monday, February 5, 1912.

The title of this paper does not, and perhaps no brief title can, convey a correct impression of the writer's intentions. It is not proposed to discuss, except indirectly Chicago's "harbor problem,"—borrowing an expression now frequently used,—nor to criticise the views of others who have discussed that question.

The River and Harbor Act of Congress approved March 3, 1909, contains a paragraph directing that a preliminary examination and survey be made of "Harbors and rivers at or near Chicago, Illinois, including Chicago Harbor, Chicago River, Calumet Harbor, Grand Calumet and Little Calumet rivers, Illinois and Indiana, Lake Calumet, and necessary connection with Calumet River, and the lake shore from the mouth of Chicago River to the city of Gary, Indiana, for the purpose of reporting a plan for a complete, systematic, and broad improvement of harbor facilities for Chicago and adjacent territory." The duty of making this report devolved upon the writer, and in consequence of existing orders from the War Department it is not proper for him to make known his recommendations until the report itself is made public by proper authority. A certain limit is, therefore, imposed upon the subject matter as well as the length of this paper. Necessarily many details and pertinent matters are omitted.

It is proper, however, to discuss in a general way the subject of what relation exists between waterways and transportation, and what terminal facilities Chicago should possess for the convenient and economical handling of her present and prospective waterborne traffic.

While every problem may have several solutions, correct solutions will only differ in detail and each correct solution must rest upon correct principles. It is perhaps too positive a state-

*Of the Corps of Engineers, U. S. A.

ment that all of the persons who have expressed themselves upon Chicago's harbor problem would have reached identical conclusions if their reasoning had been based upon correct facts and correct principles, yet it is certainly safe to say that these facts and principles could not have been known to all of these persons, for otherwise their views would not have differed so widely.

The purpose of this paper is to set forth the facts and principles which appear to the writer to govern the case of Chicago's waterways, and to so set them forth that they will form a basis for answering the question: What improvements should be made in Chicago's waterways to meet present and future demands of traffic and what terminal facilities should be provided on these waterways for handling traffic?

Cost of transportation enters into the value of every commodity useful to man. Every commodity—and the word "commodity" is used in its general sense—is transported from one point to another, from origin to destination, from consignor to consignee before it is finally consumed. A distinction should be drawn between a "freight rate" and "cost of transportation," although there is an intimate relation between them. In this paper the latter expression is intended to convey the idea of actual cost, whether exactly determinable or not. The value and importance of securing cheap transportation in the movement of commodities, and of lessening the present cost of transportation needs no demonstration. Cheap transportation opens up distant markets, reduces the cost of commodities, increases land values, lessens the cost of manufacture, and stimulates agriculture, mining, and manufacture.

A transportation line may be defined as consisting of three parts: First, the cargo carrier; second, the motive power; third, the medium on which the cargo carrier is moved. The wagon, the car, the ships; animals, steam, electric motors; wagon roads, railways, waterways. Terminal facilities include the means and appliances used at the termini or at intermediate points of a transportation line for removing from or placing the cargo in the cargo carrier, and for storage of commodities; the place or places on land or water where trans-shipment is effected and the cargo carrier remains at rest during the process of charging and discharging.

Follow a shipment of merchandise and note the various operations involved during its journey from consignor to consignee. In the general case, the merchandise is first loaded on a slow and expensive conveyor, carried thence to a storage depot located at the terminus of another transportation line for cheaper or more rapid transportation, loaded on the new line, transported by the new line, unloaded at its terminal, removed from this terminal by a third system or line, probably more expensive and

slower than the second, and finally unloaded at its destination. When both consignor and consignee are located at the termini of a transportation line, the above operations are reduced from seven to three, and when they are located on a navigable waterway they have the cheapest, best, and quickest (in most cases) transportation line at their command. If they have wagon transportation alone, then the most expensive. The relative cost of transportation by various methods is water 1 (.6 mill per ton mile), rail 7 (4 mills per ton mile), wagon 80 (50c per ton mile), transfers from 1c to 50c per ton, the former for ore, the latter for package freight.

Cheap transportation involves the use of the cheapest method combined with the least number of transfers; and to lower the cost of transportation requires the elimination, as far as possible, of the more expensive forms and a reduction in the number of transfers. In other words, use the team and wagon as little as possible, do not transfer merchandise from one system to another, and use water transportation as much as possible; or, expressing this in another way, extend existing water-transportation facilities within economical limits in order to reach consignors and consignees, reduce the length of wagon or team haul to the minimum, and eliminate, if possible, transshipment between rail and water. It would be interesting to enlarge upon the above statements, describe and discuss the various cases which can and do arise, show the limitations and cost of various methods, and argue with the adherents of rail versus waterway, but space does not permit.

The accompanying maps have been prepared for the purpose of showing the industrial, commercial, and transportation conditions at Chicago and in its vicinity, and it is to be regretted that the scale is so small that they cannot readily be seen from a distance. The situation is, however, so well known that a very brief description will suffice to show the most important points to be noticed.

Map No. 1* shows by various colors the location of industries and manufactures. The retail and jobbing trades, financial institutions, and hotels are concentrated in and near the "Loop District." Establishments transacting the same form of business, like lumber, grain, meat, fruit, iron, and steel, are grouped together along the waterways principally, but also in some cases along the railway lines. Manufacturing establishments, warehouses, etc., are located also in the greater percentage along the waterways. Residence districts exist north, south, and west of the city's commercial center. It is not necessary to give

*The maps referred to in this paper were exhibited by Colonel Zinn when the paper was presented at a meeting of the Society, but it was not practicable to reproduce them in a satisfactory form for publication in our Journal. THE PUBLICATION COMMITTEE.

statistics of commerce and manufacture; suffice it to say that a vast amount of transportation is required to move the raw material, food supplies, and manufactured products to the District.

Map No. 2 shows the railroad transportation conditions. Within the city, merchandise is moved by teams passing through the streets and by rail in the Illinois Tunnel. The streets, in the central part of the city, are so congested during working hours that the movement of pedestrians, wagons, and street cars is very slow. Open draw-bridges have their effect upon street traffic, but not to so large an extent as is generally supposed. The average period of the open draw is about 3.6 minutes and the average number of openings per twenty-four hours varies from 10 to 20 at different bridges. This period is about equal to the delay occasioned to a team moving past four cross streets. The Illinois Tunnel is not carrying its capacity of freight.

Team traffic includes the delivery of goods from retail stores to individual purchasers; the movement of building materials and city waste, of goods from wholesaler to retailer, from warehouse to store, from retailer and wholesaler to docks and railroad warehouses for shipment by water and rail and the reverse, from railroad warehouse to railroad warehouse or dock; in fine, the movement of all forms and sizes of commodities in all directions to and from all parts of the city. During the year 1910, wheel tax was collected by the city tax collector on 53,476 working teams and 800 auto delivery trucks. On November 17, 1909, the following vehicles passed the corner of Randolph Street and Michigan Avenue between the hours of 8 a. m. and 7 p. m.:

4,830 automobiles,
2,261 one-horse teams,
1,666 two-horse teams,
204 three-horse teams,
29 four-horse teams,
1 six-horse team.

It is estimated that from 150,000 to 175,000 tons of material are hauled over the streets in every working day; that 1,500,000 tons of coal are annually hauled into the Loop District, and that the various transportation lines move about 1,000,000 persons daily in and out of the Loop District.

Freight-carrying railway lines enter the city of Chicago from all directions of the compass except that portion of the circle occupied by Lake Michigan. There are twenty-three trunk lines, or railway systems, and fifty railway companies in the Chicago District, if belt lines and subsidiary corporations are included. There are five partial belt lines each connecting several trunk lines, as well as interior connecting lines over which cars may be interchanged. Maps Nos. 4 and 5 show the enormous extent of yards and trackage required to handle the

30,000 cars which enter and leave Chicago and the 10,000 cars which are interchanged between the various trunk lines daily. It is stated by Mr. Fritch, in a paper read before the Traffic Club of Chicago on November 21, 1911, that the average time required to effect the interchange of a car is 72 hours. The average time required for a local shipment to enter or leave Chicago is not definitely known, but it varies from a few hours in the case of perishable freight to two or three days in the case of slow freight.

A description of the present practice of the railroads in handling through and local freight in the Chicago District would be interesting, but it is sufficiently well known not to require space. The railroads recognize the necessity for adopting some means of relieving the congestion now existing on tracks and in warehouses, and of reducing the cost of interchanging cars of through freight, moving cars containing local freight, and handling such freight at stations, all of which is excessive and detrimental to Chicago's business interests. It is recognized that the first step to be taken in accomplishing this object is the exclusion of through freight from city tracks and warehouses, and handling it by a single complete outer belt line, provided with the necessary warehouses for separating through and local shipments destined to one or several railroads arriving in the same car. Tracks lying within the belt line will then be used for local freight exclusively.

Trans-shipment of through package freight between rail and water lines is now made at various railroad-owned docks on the Chicago and Calumet rivers; these points are indicated on Map No. 3. On the authority of Mr. W. H. Johnson about 95% of east-bound package-freight shipments in 1907 (606,000 tons) by water originated beyond Chicago, and 21% of west-bound package-freight receipts (110,000 tons) was destined for points beyond Chicago. Bulk freight is not trans-shipped.

It has been impossible to secure any accurate statistics of railway freight entering and leaving the Chicago District, but if we assume that Mr. Fritch's figures are correct and that a car represents 20 tons, the local freight amounts to 146,000,000 tons, and the through freight to 83,000,000 tons per annum.

Map No. 3 is intended to show the depths now existing in Chicago's waterways, points of transfer between rail and water lines, lighterage docks, etc.

At the present time Chicago's waterways consist of Lake Michigan, the outer harbor with its protecting breakwaters, Chicago River with its entrance piers, and branches extending north and south within the city limits, Calumet Harbor with its protecting breakwater, Calumet River with its entrance piers, Indiana Harbor and Canal connecting Lake Michigan with the Grand Calumet River, and the Sanitary District's main canal

which with the Illinois and Michigan Canal connects the Chicago and Illinois rivers. The relationship of these waterways to each other and to the industries, commerce, and railways of Chicago can be readily seen on the various maps.

Lake Michigan, the Chicago outer harbor, and the Chicago River from its mouth to Belmont Avenue on the north, and Robey Street on the south, now have or will soon have a depth of 21 ft. below Chicago City Datum, this datum being now practically at the level of the lake surface. The main river and the south branch to Robey Street are or will soon be 200 ft. wide. The North Branch has a width varying from 120 ft. to 180 ft. The entire river is obstructed at various points by movable center-pier bridges, which, however, will be replaced within a few years by single span bascule or lift bridges, the spans varying from 140 ft. to 200 ft. in width. When the improvements now in progress are completed, it will be possible for all lake carriers, with the exception of a few, to pass from the lake to Robey Street, and for all moderate-sized vessels to go north as far as Belmont Avenue.

Lines of vessels carrying bulk and package freight are operated between Chicago and points on the Great Lakes. Bulk freight is delivered in vessels on the Chicago and Calumet rivers and at Indiana Harbor. Shipments of oil are made from the Standard Oil Company's pier at Whiting, Indiana. Package freight is moved on the Chicago River from point to point by lighters. Bulk freight is generally consigned to a single point, and the entire cargo removed from the vessel at that point where it assumes the relation of local freight. The points of delivery of local freight and of trans-shipment of through freight between rail and water lines located along the Chicago and Calumet rivers are indicated on Map No. 3. The vessels of the regular lines make several landings in the Chicago River for the purpose of collecting and delivering package freight at railroad-owned docks, private warehouses, and elevators. Vessel lines, owned or controlled by railroad corporations, handle practically all of the package-freight business over railroad-owned docks. The local trade in fruit and passenger traffic is carried on at docks located near the mouth of the Chicago River. There is no fruit or passenger trade in the Calumet River except local excursion boats.

In 1910, the total receipts and shipments of bulk freight by water were as follows:

Chicago	2,877,948 tons
South Chicago	7,065,298 tons
Indiana Harbor	600,000 tons

The total estimated tonnage of package freight for 1910 is 2,363,000 tons, of which about 100,000 tons is local. About

500,000 tons of stone are brought by water annually to Chicago from points on the Sanitary Canal. Grain to the amount of 500,000 bushels annually is moved from one point to another on the Chicago River. The City Garbage Department and private disposal stations handle 556,000 tons of material annually on the river. About 50,000 tons of coal annually are handled in barges. The two lighterage companies move about 100,000 tons annually. Sand and other materials moved on the Chicago River amount to several hundred thousand tons.

Considered as lines of transportation, Chicago's waterways are not congested, except in the Chicago River near its mouth where are located the docks of all vessel lines carrying on a trade in local freight between Chicago and other lake ports. This congestion consists in a crowded condition of the river channel at certain hours of the day, and is caused by the attempted regular departure and arrival of a number of local freight and excursion vessels from their docks near the river mouth at nearly the same moment of time, and the irregular movement of other vessels between the lake and points in the river located at a considerable distance from the lake, combined with the narrowness of the channel itself, all of which causes confusion and delay. The real cause of this congestion is not the narrow channel nor the great quantity of business handled on Chicago's waterways, but is to be found in those more remote circumstances which induced the local freight lines to occupy originally and to continue the occupation of docks near the mouth of the Chicago River.

The minor impediments to free navigation on the Chicago River can and should be removed. Briefly enumerated, these impediments are insufficient depth and width, bends in channel, current, center-pier bridges, lack of turning basins, closed bridge hours, towing charges imposed by local ordinances, all of which can readily be removed at a reasonable expense.

Instead of discussing these items in detail and drawing conclusions as to what can or may be done to ameliorate conditions on the Chicago River, it is advisable to state first and briefly the impediments which exist in the Chicago District to the free and economical movement of commodities by all means of transportation, assuming that present industrial, manufacturing, and transportation conditions have now been correctly described; then to apply to these conditions the general principles or propositions governing transportation which have been previously set forth. If the principles which are applicable to the subject have been correctly and completely enumerated, if present conditions have been correctly described, and if the real obstructions and impediments to cheap transportation have been recognized, it should now be possible to determine what general

remedies should be applied, and then what special improvements should be made in Chicago's waterways.

Present conditions show a congestion of street traffic, a congestion of rail traffic within the city limits, and a congestion of river traffic near the mouth of the Chicago River. Freight movement by water is controlled by the railway lines, through rail freight is carried into and out of the city, through rail and water freight is carried into and through individual city railway and vessel terminals. There are no public docks and warehouses on the waterways for the receipt and shipment of local freight by water. City ordinances and physical impediments hamper the free movement of vessels in the Chicago River and other waterways.

Chicago business interests can derive but little benefit from the movement of freight having its origin and destination outside the city. Such freight entering the city only adds to the congestion of streets, warehouses, railway tracks, and waterways. Transfer or trans-shipment, whether between one rail line and another or between a rail line and a water line, should take place, therefore, beyond the limits of railway congestion. The railway companies and engineers propose to secure relief by one method only, that is, by the construction of a belt line uniting all of the railways within which no through freight shall pass. The proposed belt railway will be about 50 miles long, extending from Mayfair on the north, pass outside the existing belt lines, and terminate near Indiana Harbor. If this is a correct solution of the railway problem, does it not follow that the water transportation lines must unite with the railways in the enterprise, exclude from the city their through freight, and trans-ship it at a point or points located on or near the same belt line? An examination of the map discloses the fact that such points are available on the Drainage Canal near Argo, on the Lake Front near Indiana Harbor and Gary, and on the Calumet River. The proposition is, therefore, feasible.

The proper location of the point or points for trans-shipment, or designating them by the term "commercial harbor," will depend upon local features such as relative ease of approach by vessels and railroads, relative cost of land required, relative cost of construction of terminal facilities, etc., etc. An exact location need not be pointed out, but it is plainly evident that a commercial harbor should not be built within the city limits, whether on the rivers or on the lake front.

The objection may be made to the construction of a purely commercial harbor beyond the city limits, that vessels as a rule carry both local and through freight, and, therefore, two landings would be required, one at the commercial harbor and one in the Chicago River, instead of one as at present at the latter locality. In reply to this objection it need only be stated that

under present conditions, several landings are necessarily made by package freight vessels entering the Chicago River, and, in fact, that through freight now delivered at several landings in the Chicago River would all be delivered at a single landing in the commercial harbor. The questions, who should build the commercial harbor and how can the railway and steamship companies be compelled to use it will not be discussed. If it be admitted that one or more commercial harbors should be provided in the Chicago District, legal and financial means will no doubt be forthcoming for their construction.

A commercial harbor, whether located on an interior waterway of small depth or upon the lake, must have ample room for the anchorage and movement of vessels, adequate pier space, and warehouses of sufficient capacity to handle the probable amount of freight passing through them, machinery for transferring all classes of merchandise from vessel to car or warehouse, railway tracks, etc. It is not the purpose of this paper to explain or discuss the details of terminal facilities.

If the proposition to separate the movement and trans-shipment of through and local freight is the correct one, the solution offered for the location of commercial harbors is believed also to be correct; it now remains to consider the question of the proper method of handling local freight, that is to say, of handling shipments of merchandise by rail or water whose origin or destination is within the limits of the congested transportation district.

Merchandise or commodities of one kind or another are consumed or manufactured in every building, in every building lot, in every acre of the Chicago District. Shipments of commodities, therefore, originate or are destined to these points, and the transportation of these shipments is effected or desired by consignee or consignor, consumer or producer, by the cheapest method. It is obviously impossible to so extend the waterways or the railways to reach every consumer or producer, and thus to eliminate team traffic. Railways can be extended more cheaply into factories and warehouses as a rule than waterways, but within the limits of reasonable cost, waterways may and should be extended. It cannot, however, be questioned that existing waterways should be used to the fullest economical extent for the delivery and receipt of local freight, with the distinct purpose of reducing the length of team haul and eliminating transfers from vessel to vessel or from vessel to railway lines.

Railway transportation lines extend their tracks to reach points of freight production, the limit of extension being determined by density of traffic, either actual or potential. Water transportation lines will also extend their terminal facilities, if justified by density of traffic, all other things being equal. But

in the Chicago District, all other things are not equal. Vessel movement is hampered by physical, commercial, financial, and legal conditions.

The economical movement of local freight seeking water transportation requires that suitable terminal facilities should be provided at points on all of the waterways where density of traffic warrants it. If we assume a certain distance as the limit of economical team haul, twice this distance will represent the proper spacing between terminals on the waterfront. It may be safely said that such facilities should be provided along the Chicago River at intervals of about one and a half miles, that they should be provided at one or more places on the Calumet River, and that they are not now required along the lake front of the city of Chicago. These facilities, consisting of docks, warehouses, machinery, etc., for the handling of package and bulk freight cannot be provided by water transportation lines economically and must, therefore, be provided by the municipality.

Consignments of bulk freight in entire cargoes will, as heretofore, seek the privately-owned consignees' dock; to impose the necessity for trans-shipping such cargoes would eliminate the advantage of water transportation.

It cannot be objected to this scheme that the Chicago River is not a suitable channel or that it is too much obstructed to be economically navigated, for, as previously stated, every impediment to its free navigation by lake carriers can and will be removed, if the merchants and other citizens of Chicago make an effort in that direction.

The exclusion of through freight from the river, the distribution of local terminal facilities along the river, instead of their concentration near its mouth, will relieve street and railway congestion within the city limits. A proper reorganization of railway freight terminals throughout the city will assist in producing the same result.

It may be said that the transportation of local freight in the river will seriously inconvenience passenger and team traffic in the streets by the frequent opening of draw-bridges. It has been shown that the delays occasioned to street traffic by open bridges during 24 hours are not serious, but the advantages of extensive water transportation facilities to the business interests of Chicago are and will be so great that a solution of the difficulty can and should be found in the construction of street tunnels under the river at advantageous points. The completion of the proposed passenger subway will remove practically all complaint against open draw bridges. The Illinois Tunnel, a freight carrying subway, about 65 miles in extent under the city of Chicago, now crosses the river at the following points: Taylor Street, Polk Street, Van Buren Street, Jackson Boulevard,

Randolph Street, Lake Street, Kinzie Street, Indiana Street, Market Street, Franklin Street, Wells Street, North State Street, Rush Street. After its purchase by the city and its enlargement to accommodate full-sized railway freight cars, team traffic will be greatly reduced.

The plan suggested herein of providing terminal facilities for the handling and trans-shipment of waterborne freight,—that is, by a single terminal for through freight located at a distance from the business center of the city and a number of terminals within the business district for local freight,—is similar to that proposed by the Barge Canal Terminal Commission of the State of New York for handling the traffic of the new barge canal at the harbor of New York.

Many widely-differing suggestions and opinions have been advanced as correct solutions of Chicago's "harbor problem." Plans for harbors have been submitted to the sub-committee on harbor development of the Committee on Harbors, Wharves, and Bridges of the City Council of the City of Chicago. These plans and much of the testimony taken by the sub-committee show a belief on the part of many well-informed people that Chicago needs a harbor somewhere on the lake front between Lincoln Park on the north and Jackson Park on the south.

The assumed necessity for a lake-front harbor arises apparently from the belief that the lack of such a harbor has caused a falling off in Chicago's waterborne traffic, and that the Chicago River is already overtaxed as a waterway, or too small and tortuous to admit a modern lake carrier.

The benefits which will arise from the construction of a lake-front harbor are assumed to be that terminal facilities will be furnished for a great number of steamers handling package freight, fruit, and passengers, which steamers now dock in the congested river; that the passenger business on the lake will be greatly stimulated because the embarrassing and even dangerous current in the river will not be encountered; that public docks can be provided accessible to any and all vessels on equal terms; that reduced dock rentals and reduced freight rates will be secured for the merchants of Chicago; that opportunity will be available for the establishment of independent steamship lines; that the elimination of port charges and a reduction of time of vessels in port will result; that relief will be afforded to congested railway terminals.

One of the real causes in the diminution of Chicago's waterborne traffic is the control now exercised over that traffic by the railway lines of the United States, and not the lack of harbor facilities. The construction of a harbor will in no wise alter this condition of affairs, and without railroad coöperation, given willingly or unwillingly, no harbor, however modern or well

supplied with terminal facilities, can be a success for the transfer of through freight.

A lake front harbor within the city limits will be a most unsuitable place for the transfer of through lake and rail freight, because it is impossible for all the railways to reach it and even difficult for one railway to reach it with suitable trackage, and because in no way will it relieve the present congested condition of railway freight movement.

Again, as a place for the receipt and shipment of local freight, it can have no usefulness except for a limited area within economical team or lighterage haul. The long team haul, or the transfer to rail and subsequent team delivery required, utterly discredits it as a place for the shipment and receipt of the entire local freight movement of the city. The use of lighters in connection with such a harbor is analogous to team delivery, the lighter having a much more limited sphere of usefulness than the team, although much cheaper for a long haul. As well suggest that the Pennsylvania and Illinois Central Railroad Companies be compelled to remove all of their railway tracks lying within the city limits, as to suggest the closing of the Chicago River to all lake carriers.

Discussion.

Ernest McCullough, M. W. S. E.: The conditions in Chicago are analogous to those existing where navigable rivers enter a sea. The best place for a port to be built is where the deep-water vessel must stop in its passage up the river and goods must be shifted from train to vessel. In trying to establish Astoria (Oregon) as a competitor of Portland, economic conditions were encountered which for many years have baffled the ambition of the business men of Astoria; but now Portland is growing rapidly and bridges across the river are such an important means of communication for the residents that strong objections are made to vessels going above the main bridges over the river at Portland. The port of Portland will probably keep moving down the river and some day it may land in Astoria. Is the condition not the same in Chicago? At the mouth of the river we have a great city and the street traffic is enormous. Every time a bridge is opened to allow a vessel to go through, much annoyance, and oftentimes considerable loss, is caused. I doubt that we can always keep the Chicago River open as a harbor without lighterage. I do not believe we can do away with the expense of transfer, even though that expense may be very high.

The question of team haul is one that appeals to engineers, because it is known that in handling a contract economically there is a point where the team must be disposed of. When the expense of team haul is added to the cost of transportation between terminals, the selling price is increased. The residents in suburban

villages around Chicago know this, for in many of them meat is cheaper than in some parts of Chicago, because of the fact that meat is put on cars at the packing house, and taken off on a man's back and carried into the butcher shop; whereas in Chicago it is often hauled many miles by wagon.

So long as bridges are a source of annoyance to many people and open bridges an expense to business men who use the streets, it will be a question whether the river can be kept open for the use of lake carriers. The author might profitably dwell somewhat longer on this phase of the subject, for it is of great importance.

F. E. Davidson, M. W. S. E.: Some twelve, or rather fourteen, years ago, I devoted a good deal of time to the study of this general question. At that time I was in charge of the re-designing of the intercepting sewer system which was afterwards built in Chicago. I had made a careful survey of the "Sag" cut-off from Blue Island to the Drainage Canal, and the result of my studies of that survey was the conclusion that the Sag cut-off was the most feasible and economical connection which could be made from the lake to the Drainage Canal; that the future location of docks and facilities for handling heavy lake traffic would be at the Calumet Harbor; that ultimately heavy lake freight would be handled only on the Calumet River. I made a prediction, in a report to the Commissioner of Public Works of Chicago, that in my judgment the time would come when there would be no movable spans across the Chicago River; that traffic on the Chicago River proper would all be by lighterage, and that heavy freight would all be transferred and handled at the Calumet Harbor.

I would ask the author if he has made any estimate of the cost of deepening the proposed Sag cut-off to permit the largest lake boats to go from the lake to the Drainage Canal by way of the Sag, as compared with the cost of not only straightening out some of the bad bends now existing in the Chicago River, but also maintaining the Chicago River proper at a depth sufficient to handle the larger lake freight carriers? In other words, as a simple economical proposition, considering only first cost and maintenance, would it not be better to spend the money in deepening the Sag cut-off and maintaining it, rather than to try to maintain the Chicago River for deep-draught vessels? I would suggest the maintaining of say 10 to 15 ft. of water in the Chicago River, building fixed bridges for all the streets which cross the river, and using the river for lighterage purposes only, as well as for drainage from storm-water sewerage.

Captain Charles Campbell: I am going to talk from the standpoint of a ship master, whose experience has been acquired in handling vessels under all conditions, in various ports of the world.

I have given careful study to this question of the port of

Chicago, and am interested—with the completion of the New York State Barge Canal—in the operation of a line of freight vessels between the port of Chicago and the port of New York; incidentally, I may say, to extend, when profitable, to Boston, Baltimore, Newport News, Philadelphia, or any other point along the coast.

Does any one know of any seaport in the world where the commercial piers reach out to the seaboards? Is it not customary in all great seaports to bring the carrier as near to the initial point of receipt, or the final point of delivery, as possible? The author asserts that we must eliminate the rehandling charges to secure the best results. We all know the economy of water-borne transportation. Now let us assume that freight is being carried from the lower lakes,—say from the port of Buffalo,—or, with the completion of the New York Barge Canal, that the freight is being carried from the seaboard through to the port of Chicago,—and that the outer harbor has been constructed. Chicago proposes to use the lighterage system, as is done in the port of New York. Against every hundred pounds of freight there is an additional charge of 3c per hundred pounds (60c per ton). Please note that this charge is made by the railroads just as well as by the operators of these lighters that we call independent companies. To be ultra conservative in this respect, let us assume that we are only to impose a charge of 25c per ton for every handling. The boat is docked at this outer pier. The cost to handle the freight from the vessel to the pier is 25c per ton; from pier to lighter, 25c per ton; to land it on the bulkhead after getting into the river, 25c per ton, plus again the cost of carriage from that point to the final point of delivery. This indicates that in the aggregate those charges nullify all the beneficial effects of water-borne transportation. It would be far cheaper, under such conditions, to haul the freight by rail, especially if there was a spur that ran into the plant where it was to be delivered.

Mr. Davidson spoke of the existing congestion, and of the benefits of fixed bridges across the river, pointing out the inconvenience to individuals for the benefit of commerce. Suppose that commerce were hauled to or from the outer piers by truck; is it not clear that the already intolerable congestion in the streets today would be increased? The traffic squads would never be able to keep those streets clear. Chicago is quite different in its situation from New York, where there is a river on each side of Manhattan Island. There is also the Brooklyn shore, and the New Jersey shore. Here there is but the two sides to a river not 200 ft. across—though it might be made wider by cutting out the abutments foolishly placed there for bridges. Suppose those draws were opened at the approach of a vessel. How long would the detention be? Nothing to speak of. Of course, one might be in a hurry to get across, one might be late in getting down town to

business, but should individual cases be allowed to militate against the commerce of a great city like this? No.

Another logical point which has been brought up this evening is, that Chicago is a great *entrepot,*—a receiving and distributing center. Mr. Barlow, the traffic director of the Chicago Association of Commerce, has said that substantially 10% of all the freight entering Chicago is for local distribution, and that 90% is merely a trans-shipping proposition; why should this be brought into the congested center? Why not transfer it in a remote part of the city where the realty is ample and cheap, as is done in New York? The present dock commissioner in New York, Calvin Tomkins, has obtained an appropriation of $65,000,000 for the express purpose of segregating these two distinct branches of commerce. He has been authorized by the New York legislature to acquire and equip realty, and is now doing so in Jamaica Bay and other remote points of the ports for foreign commerce. If this method were followed in Chicago, nine-tenths of the intolerable congestion could be relieved.

There is one thing sure; this commerce must be looked after. It is a known fact that the reason manufacturers in this great, inland center cannot enter the markets of the world in competition with alien manufacturers, is the enormous cost of transportation between here and the seaboard. The more that is done to facilitate and economize on the transportation and handling charges of manufactured products, the sooner will the markets of the world be reached.

The paper presented this evening is an admirable one, and I am convinced that it merits the highest endorsement.

Hugh J. Fixmer, ASSOC. W. S. E.: For over four years I have made a study of the general problem of traffic congestion. I have appeared before the harbor commission and also the committee of the City Council on harbors, wharves, and bridges, advocating a plan having for its object relief from general transportation congestion through the adequate development of our river or inland waterways.

Briefly stated, the plan involves building an adequate canal at about Fourteenth Street, connecting the South Branch of the Chicago River with the lake. This canal would be about three-quarters of a mile long, about 300 ft. wide, and 27 ft. deep. It would cross but four traffic streets, which could go over the canal on bascule bridges, or under it, in wide arcades, parallel to the proposed street-car subways. This canal would connect almost directly with the great Drainage Canal, which, as you know, is a wide, deep waterway. Along the Drainage Canal are wide stretches of land suitable for factory sites and industrial purposes, railway facilities and cheap power. A study of the situation will show that the industries extend only about three miles inland from the

lake, the remainder of the waterway being practically vacant. This undeveloped territory is due to a lack of proper outlet either way. North of Fourteenth Street, to the mouth of the river there are about twenty bridges, together with a narrow, tortuous channel combined with an adverse eddying current. The author has pointed out the undue congestion at the mouth of the Chicago River. This condition, combined with the previously named obstructions in the river, has confirmed in my mind that a canal at about Fourteenth Street, furnishing a free, open outlet to the lake, is a real necessity if the waterway business is to remain and grow within Chicago proper.

It has been the earnest hope of the people of Chicago that the costly Drainage Canal would become a part of The Lakes-to-the-Gulf Waterway. The Panama Canal will soon be completed, and if Chicago is to get its proper share of the water-borne traffic, north from the Gulf and west from the Atlantic, it must provide proper facilities. Along the Drainage Canal and river, when properly connected with Lake Michigan, can be located all the necessary warehouses, terminals, and various industries which can be easily reached by teams and the workers without bringing them down town to add to the congestion. Incidentally it may be mentioned that by reason of having an outlet at Fourteenth Street, all the bridges on the South Branch from Twelfth Street to Lake Street could be made fixed and of the full street width. This part of the river would then serve only as a sewage conduit and as a waterway for tugs, lighters, and other small craft.

The construction of a lake front harbor should be limited, in my opinion, to perhaps two piers north of the present river mouth, and about four piers at the mouth of the proposed canal at Fourteenth Street. One of the piers at each harbor could be used for passengers and recreation purposes as well as for handling local package freight; the other piers to serve the *few* railroads, including the proposed municipal belt line having access thereto.

I heartily agree with the author that the through traffic should be handled outside of the congested zone. Adequate water-rail terminals should be located along the Drainage Canal and freight picked up by lighters at convenient free docks along the river, the necessity for team haul being thereby reduced. The people of Chicago are mainly interested in keeping the business *in* Chicago. A large city has been built here; people have located here; workers have bought their homes and the great majority are dependent upon the proper indiscriminate development of our city. It is logical, therefore, to develop our natural waterways and seek to locate industries along their course, rather than concentrate business in one spot to the detriment and inconvenience of the people as a whole.

As for the railroads, I believe that their congested freight

terminals should be taken out of the center of the city, and the space they now occupy devoted to business purposes, such as office buildings. The terminals could be located along the canal where land is much cheaper. I have recently seen the statement that an ordinary freight car uses space valued at about $20,000 a year; that is, if this space were properly used as conditions demand, it would be worth that sum. This is a tax which is paid by the consumer or manufacturer in some form or other.

The author proposes a plan having an outer belt line, or utilizing, possibly, the present belt lines, running, say, from Mayfair across the Drainage Canal to the Calumet district, the idea being to keep the through-traffic out of the congested district. Freight to be transshipped by water would be taken on this belt line to some point on the Drainage Canal having proper facilities for transferring the through freight directly on to boats going either down the canal to the Mississippi River or out on the lake to other points. It is not my undertsanding that the author proposes anything like a new belt line to go to Milwaukee, but simply to intercept the through freight and not have it come into the congested yards as at present.

W. E. Symons, M. W. S. E.: The paper that has been presented this evening is a very interesting one, and one that should be not only thoroughly discussed, but be given a great deal of thought and study by all, with a view of considering the subject again, later on.

In regard to the possible future development of the waterways as outlined by the author, does not the plan proposed really embody at present the nucleus to extended waterways for other purposes not mentioned? I am inclined to think that Chicago should not be entirely isolated from deep-water transportation. From the standpoint of patriotism, and as a matter of protection against foreign invasion, I think that our war vessels should have access to Chicago through a deep-water channel to accommodate ships; not necessarily the heavier ones, but ships of at least as great draft as those of any foreign nation that could approach Chicago, or any other cities not on the sea coast; for instance, vessels of draft equal to that of English ships that could be brought up the St. Lawrence River and into the Great Lakes from the other direction. Of course, we are living in perfect peace and harmony with England, and I know of no reason why this happy relationship should change. But the bitterest quarrels between individuals, corporations, or nations usually occur on the severing of bonds or relations between those who by ties of blood, contractural relations, or treaties are supposed to be very closely allied. Under our treaty conditions with England, as I undertsand it, we are not allowed to fortify the Great Lakes. England, however, could bring through neutral waters, to a point near Montreal, a number

of medium-draft armored ships, without violating any neutrality laws or treaty agreements. And in case of severing existing treaties between the two nations, and resorting to hostilities, before we could do anything at all they could get an armored fleet into the Great Lakes that would raze such cities as Buffalo, Cleveland, Chicago, and Milwaukee to the ground, and we, as a nation. would not only be humiliated, but would have to sue for peace on the best terms possible. If Chicago were accessible from the South by a deep waterway, through which our vessels of equal draft to those of a foreign power could be brought here, they could be kept just as close to Lake Michigan as any foreign power could keep its war vessels to our boundary line near Montreal. Then the defence of our great cities on the Great Lakes would be assured.

The thought comes to me that possibly our Government officers have something of this kind in view, as supplementary to the improvement of waterways at Chicago, that would be a nucleus to, or form a connection with, a future deep waterway.

Aside from the foregoing, the question of transportation is, of course, a very important one, and one in which all those concerned in the growth of the country are, or should be interested. As some one has said this evening, however, it should be borne in mind that the number of times freight is handled,—package freight or other kinds,—largely governs the cost of its transportation. It is possible for the people of a community, or an auxiliary transportation company, to be misled into thinking that they are effecting a great economy in a proposition of this kind, when in reality the result might be the reverse. The average public mind is not thoroughly familiar with this fact, which is one of the reasons that there is so much dissatisfaction in connection with the question of long and short haul on railways. The ordinary citizen, be he consignor, consignee, or lawmaker, naturally thinks that if a railway company can haul freight 200 miles for a certain sum, it should haul it 100 miles for half the sum, and frequently the man who pays the freight believes that he has been mistreated if he finds that freight is hauled to a point beyond him for almost the same price that he pays. The freight charges, no matter how short the haul, absorb two terminal-handling charges. The longer the haul, the cheaper the haul per mile, in so far as the terminal charge for handling controls, for on a long haul this item of expense is spread out until it almost disappears. So, in the introduction and use of canals or rivers for local package freight, in connection with through transportation lines, the fact must not be lost sight of, that in order to utilize them to their full capacity we might find ourselves in some instance carrying a double terminal charge that would not exist if the railway or steamship line could

receive or deliver the shipment at the point of origin or its final destination, respectively.

Assuming that the feature first mentioned is feasible and may have been contemplated by the author, or those whom he represents, we might carry the matter further and assume that later on heavy, coarse freight, such as coal, pig iron, and certain grades of lumber, would be moved long distances by water in or out of Chicago. Then the water feature becomes a valuable adjunct to the railways and to the communities in general, and particularly to the shipper.

Transportation is, of course, the physical act of transporting something from one point to another. It may not be generally known by the shippers and merchants that the cost of transportation is governed largely by the speed at which it is hauled. Much coarse freight is shipped in trains that are hauled at high rates of speed, resulting in a cost for moving the freight far in excess of that on the same commodities shipped at a lower rate of speed. The result is that low-grade, coarse freights are not infrequently handled at a loss to the transportation companies, after operating expenses and the interest on the investments are taken care of.

If our railways can be provided with means for moving low-grade, coarse freight at a low rate of speed without interfering with the movement of commodities that justify a higher transportation cost for moving, then by a division of the different commodities and different classes of both freight and passenger traffic, so that the movement of one would not interfere with the other, our transportation companies could operate much more economically. The bringing into use of our waterways, such as canals, canalized rivers, and lakes will, of course, materially aid in this direction. Where water transportation can be used as an auxiliary to a railway line, it will provide means for increasing the tonnage capacity of the railway lines, and if it touches common points, it will provide means for handling the coarse, low-grade freight and obviate the necessity of providing additional main-line tracks.

It may be reasonably anticipated that in the near future the fastest passenger trains on all the principal trunk lines will require a clear track for movement, and when approaching large cities or congested centers of population, the local passenger trains will require a different track in order to avoid interfering with the fast through-passenger trains. This, together with the possibility and probability of electrification of railways in and around our large cities, suggests the handling of much of the passenger business between large cities not far apart by electricity. That feature being taken care of in this manner, the next in order would be the fast-freight business, which includes live stock, dairy products, and perishable commodities,—fruits, vegetables, etc.,—that must be provided daily for the markets in our large cities.

April, 1912

Unless some of the present waterways, and such artificial ones as may be provided in the future, are utilized for the low-grade, coarse freight, and by this means relieve the congested condition on the present tracks, it will be necessary to build considerable additional railway mileage in the near future. Again, if the low-grade freight tonnage is not partially removed from the main lines, thus getting this traffic out of the way of the passenger and fast-freight business, which must move at higher rates of speed, then the carriers will in all probability be justified in asking for an increase in the rates paid on these low-grade freights, for if forced to carry them at high speeds, they should receive a rate of compensation commensurate with the cost of service rendered.

In regard to the advisability of utilizing our waterways in and around Chicago for transportation purposes, we should not overlook the question of the present and probable future sizes of our city, and the consequent necessity of increased means of transportation in order to reach all parts of the city either by rail, water, or both. In order to emphasize this point I take the liberty of quoting what one of our English cousins has said about us,—a gentleman who is an authority on the growth of cities. At the time of the Association of Commerce Committee's banquet in 1909, a delegate from London had the following to say with reference to Chicago:

> "I have been making comparisons with London. I believe that in forty years this will be the largest city in the world (Chicago). In fifty years Chicago has added 2,000,000 to its population. During forty years it has added an average of 75,000 a year. Its natural conditions, railroad facilities and other advantages will continue to operate to its advantage. There is no questioning, to the reasoning in my mind, that it will become the metropolis of the United States within twenty-five years. Sooner or later it will do what New York has done, absorb its rapidly developing suburbs. Greater Chicago will add a million to its population at one swoop. The city has a right to do this. Figuring natural percentage of growth from the past, all arguments favor a city of 13,000,000 by 1950. London has about 7,000,000 and is 1,800 years old. Chicago is but twenty-five years old. It now has no competition in population except in New York and London. London lacks the possibilities of expansion and sooner or later will reach its maximum growth."

So that, regardless of the features of the proposed plans that are not fully presented to us, there is no question at all but that the present and probable future conditions of Chicago, in the matter of transportation, are such that we are well warranted in giving support and endorsement to improved waterways, both as

a means of facilitating transportation around our city and on account of the possibility of there being a nucleus to other avenues of transportation far beyond our city limits.

C. B. Lewis, ASSOC. W. S. E.: I am comparatively a newcomer to Chicago and for that reason get a little more of a perspective of the situation than some of those who have lived in these situations all their lives.

I notice the Drainage Canal was built primarily for drainage and not for navigation. It is my understanding that the ship men say conditions, from the navigation point of view, were a great deal better before the canal was built. One of the obstacles to navigation which no one has, apparently, touched on this evening is not only the bridges and curves in the river but the current, and if we are to keep out of trouble with the state of Missouri and the city of St. Louis we must dilute the sewage, and we must have current. We are now allowed to send a maximum of 10,000 second feet down the river, and are negotiating, I understand, with Canada for permission for an additional 4,000 second feet through the Sag channel.

As to the lake front harbor, it has been my understanding that we are not to have a double handling of freight there; that railroad spurs are to be run on to the piers, that there will be railroad communication in some form. This would accommodate 90% of the freight to be handled and the remaining 10% would not seriously congest the streets.

The suggestion was made that we build a belt line railroad outside of all the other belts. We already have a belt starting at Waukegan and running outside of the others. When we extend those belts further and further out, are we not running the risk of gradually sending business away from Chicago? We are advised to annex our suburbs. That is a point very well taken. We cannot annex beyond the Wisconsin state line. As has been stated, we already have a belt starting in Waukegan. The next step is to start a belt in Milwaukee. One of the great drawbacks which Chicago has now is allowing business to go to Milwaukee.

Mr. Davidson: In connection with the improvement of the Chicago River and the operation of the Drainage Canal, the probable enormous future growth of Chicago should be seriously considered. I am advised that the Chicago Telephone Company estimates that the population of Chicago in 1930 will be 5,000,000, and that the same company made an estimate in 1890 of what the population would be in 1910, and came within about 5,000 of the correct number. So we may assume a population of Chicago in sixteen years from now of about 5,000,000. Chicago is growing rapidly. The Drainage Canal as it is operated today is taking only about enough water to dilute the sewage as it is, and what will be done with the sewage when the population is

doubled or tripled? My own belief is that in time Chicago will have to rebuild its entire sewerage system. The storm water can probably be diverted to the river and the Drainage Canal, but the question of sanitary sewage will have to be taken up and disposed of in some other way.

Colonel Zinn: Mr. G. M. Wisner made a report to the Sanitary Trustees, showing what the city would need, and he proposed to spend $15,000,000 to do what has just been suggested.

Mr. Davidson: I made a report fourteen years ago, along the same line, that I believe was published in the *Engineering News* at that time.

Referring to what Captain Campbell has said about 90% of our freight being through-freight, and having in mind the future growth of Chicago and the growth of manufacturing industries along the Calumet River, why not have a cut-off through the Sag or somewhere on the south, divert the through-freight south of the business district of Chicago, and leave the 10% to be handled by lighterage?

Not long ago I saw an interesting map,— in the City Engineer's office, I think,—of the actual outlines of one of our large lake steamers lying in the Chicago River. The State Street bridge was open, and to let the boat through required three bridges to be open at once. This question of interrupted traffic is a serious one. The business of Chicago is done mostly in the loop district and probably will always be done in the very restricted area of the river on the west, Twelfth Street on the south, and the river on the north. Therefore, why not divert through-freight by way of the Sag and the Calumet River, and make the Calumet River the harbor of Chicago?

H. H. Evans, M. W. S. E.: One of the speakers pointed out the probable future growth of the city, and in my estimation that will have an important bearing on the harbor situation in Chicago, for the reason that the present commercial district on the main stem of the river, and adjacent thereto, will probably cease to be a trading district and evolve into a purely office district in the not far distant future.

In the first place this central district is small, and the territory fringing upon it is railroad property, which can hardly be converted into commercial uses. In addition, the railroads interpose a barrier to its expansion. This district is now largely occupied by offices, and there is an increasing tendency to concentrate there. Head-office business and larger business is of such a nature that it must inevitably concentrate; so much of it must be transacted through personal conferences and interviews, that the offices—financial, legal, commercial, engineering, and industrial—must be concentrated in a district so small that its extremes are within easy distance of each other. There is not room for territorial expansion

without going beyond these extremes. We have placed a 200 ft. limit on the height of buildings, so that this height measures our maximum provision for office room, and as the need for office room grows, the tendency will be to drive further out along the river such industries as the stores, the manufacturing tailors, the jobbers, and places of that kind. When that situation is brought about, there will be less teaming through the present loop district, and less traffic on the river. The trip up the river will grow more difficult because of its length and because of the increased size of boats. With the growth of the city, there must necessarily be more and more bridges provided. Each bridge makes the navigation of the narrow channel the river presents, more troublesome and increases by that much the chance of a vessel getting into difficulties. If the Chicago River were a clear channel between shoals, the responsibility upon the captain of a ship in navigating such a narrow, tortuous, crooked channel with currents would be sufficiently nerve-racking. The presence of bridges adds to the difficulty. For instance, the captain has his vessel well under control; he whistles for a bridge to open, and when it does not respond promptly, he is obliged to stop, back, and thereby loose steerage-way. The "take" of the screw in backing throws the boat athwart the channel; his vessel becomes unmanageable; the current catches the stern and twists the vessel across the stream and wedges her there; and if the vessel escapes without a couple of plates stoved in she is lucky.

I think many have been somewhat confused in their ideas of the word *harbor*. It seems to me that the harbor situation in Chicago divides itself into three parts, each of which is more or less distinct,—namely, city harbors, industrial harbors, and what we might term commercial or transfer harbors.

The city harbor is for the purpose, principally, of handling passengers upon excursion vessels, produce and package freight, and possibly for receiving merchandise, storing it, repacking and reshipping by rail or otherwise. This is now done on a large scale in the Pugh terminal in Chicago, where package freight is unloaded from vessels, stored in a section of the warehouse rented by the year by a jobbing firm, and in many cases repacked and reshipped to country merchants.

The industrial harbor is for the purpose of handling bulk freight in vessel loads, either as raw material for manufacture or as a coarse commodity for subsequent distribution. It is generally used by a wealthy corporation and, if there is any economic necessity for it, the corporation will provide it as a part of its plant.

The commercial or transfer harbor is a transfer station between transportation agencies, principally for the transfer of freight from the larger, long-distance vessels to smaller ones. The latter

distribute the freight up and down the coast or to lighters; they also transfer it from vessels to railroad trains for delivery to other points.

The three classes of harbors just described may be embodied in one set of harbor works, or harbor works may be provided to care for one kind alone. Gary furnishes a good example of an industrial harbor; Fishguard, the English landing place of the Cunard liners, of a transfer harbor; Havana, of a city harbor.

The corporation will take care of the industrial part of the harbor situation. The city harbor should be on the lake front, free from the hazards and expense of river navigation. As to transfer, or harbor provision intermediate between industrial and transfer, it seems to me that, as the river becomes harder to navigate, the tendency will be in the direction of the Calumet district, where the railroad connection is somewhat better than along the main river.

As far as securing railroad connection with a city harbor at the lake front is concerned, under the recent enabling act the city is empowered to construct railroad connections to any harbor it may locate there, and in addition the State Railroad and Warehouse Commission now has the right to compel switching connections between railroads. Consequently, should the city construct a harbor on the lake front for city purposes, and find it desirable to connect it with the railroads, it would be possible for the city to construct its own railroad to connect with the other railroads. Or, by constructing a short length of railroad, it could bring proceedings before the State Railroad and Warehouse Commission and compel connection with that short stretch of city railroad to the other railroads in the city to secure facilities for transporting and transferring railroad cars.

Mention has been made indirectly, this evening, of the necessity for a harbor more or less independent of the railroads. The city recognizes this. It has at present a commission known as the Inter-Lakes Traffic Commission, designed to be a kind of band of missionaries, who are to confer with the officials of other lake ports and secure their coöperation towards providing independent city harbor facilities.

In some places there are city harbors alone; in others, industrial harbors alone; and in still others the various kinds of harbors are found to be provided by one set of harbor works. Where there is such a combination,—where a harbor handles more than package freight and excursion business alone,—there is this angle: With efficient planning, it is possible to eliminate a good proportion of the handling charges over the docks (now militating against water shipment), by providing economical unloading and handling devices at the docks. These facilities cannot be scattered up and down a long stretch of river, for a vessel might not be

bound to that point, or, to reach it, might be at the cost of hazardous navigation. Nor can every form of facility be provided at a particular ship berth. What can be done is to provide apparatus to care for certain classes of freight, and so design the harbor that a vessel may readily shift from point to point to use the apparatus, or so much of it as is not portable.

A ship comes in with a mixed cargo and berths where it is economical to discharge a portion of her cargo. To secure cheap freight charges through reducing handling charges, that vessel must be enabled to shift readily to another point where there are facilities for handling the other portion of her cargo. If a harbor is constructed where navigation is easy, and the use of a tug is not required; if a vessel is not compelled to traverse a river, where slow-opening bridges are encountered; if the basins or slips are wide enough to permit manoeuvering without danger of collision, yet not so wide that a line cannot be laid out readily to a bollard or mooring bits on the opposite wall, to assist the vessel into the stream; if the conditions are right that a vessel may shift readily under her own steam, and the facilities are there, it will be possible for a vessel to avail herself of a mixed cargo without the charges being greatly in excess of those for a bulk cargo. It will also be possible for a vessel to bring one commodity to this port and leave with another without an expensive shift from the point of discharge to the point of lading, and for a vessel trading to such a port to save a considerable amount on her coal, because such a harbor would certainly have properly-equipped coal docks. At these docks the colliers would discharge their coal by automatic machinery, which would store it in coal pockets and deliver it through chutes into a vessel's hold when she came under the pockets. Coal is ordinarily handled in baskets, holding anywhere from 40 to 150 pounds, which are passed along decks and into the hold by manual labor. This method adds sometimes as much as $1.00 per ton and never less than 25c per ton.

I have been around a harbor laid out along these lines, a good deal,—the harbor of Buenos Aires, in South America, perhaps one of the finest in the world. A transatlantic ship unloads her passengers and higher class of package freight at the upper (or north) end of the docks. Then she may steam down a couple of basins to a warehouse where she discharges her rougher freight and up-river freight (the latter being picked up by the river steamers which come there for it). Next she will go down to the coal docks at the south end, where she fills her bunkers. She turns in the basin below the coal dock and then goes under a grain elevator on the outside of one of the basins near the north end and gets a lading of grain. Finally, she goes to the north end and picks up passengers and package freight and steams on out (being headed right from the turn at the coal docks) for Europe. This

is done perhaps without even the use of a tug during the whole performance, or certainly no more than a tug ahead. In this way the ship is enabled to handle her cargo much cheaper than if she had to go alongside of a single dock and pass everything over the one dock.

One of the speakers brought up the possibility of bringing battleships into the Great Lakes. If this were done, we might run foul of the Webster-Ashburton treaty, or at any rate get ourselves disliked. Our treaty obligations limit us to keeping one obsolete gunboat on the lakes. (The Naval Reserve vessels not being in the regular service, they are not held to be within the treaty restrictions.) The draught of battleships is so great that it seems to me the heaviest class of man-of-war that a hostile power could bring into the lakes would be a protected cruiser, and that class of vessel is not so much a menace as it might appear, because it is vulnerable to secondary sizes of guns. A 6 in. gun will put one of them out of commission. None of them carry guns of heavier caliber than 8 in., and most of them are armed with 6 in. guns, or smaller. A 6 in. gun is readily transported on a railroad car, and can be mounted on shore to give a range which will equal that of any gun on a ship mount to be found on a protected cruiser. It would be much easier to improvise fortifications in a limited space of time with guns of sufficient caliber than it would be out on the seaboard where there is liability of attack from hostile battleships. There is also the possibility of mine defense. Most of the lake front of lake cities has comparatively shallow water, and it is quite easy to mine the water in front of such cities; certainly it would not be difficult in the case of Chicago's harbor.

J. A. B. Tompkins, M. W. S. E.: In Milwaukee an attempt is being made to work out a solution of the transportation problem by forming an outer harbor at Jones Island, which lies immediately in front of the city. The business that simply passes through the city is to be handled by a belt line of railroad to be built and owned by the city, terminating on Jones Island,—a line to reach out around the city and intersect any railroads which now enter or may hereafter enter the city. The plan further contemplates the complete improvements of the rivers of Milwaukee,—the three rivers which constitute the inner harbor,—to develop them to their utmost, and to handle all local business on the rivers as far as possible. Milwaukee does a large business in importing coal and shipping it to the west. I do not know what the figures are for 1911, but in the neighborhood of five or six million tons were handled, the larger portion of which was probably shipped west. This business is handled by several companies located on the rivers, which are narrow and tortuous and spanned by numerous bridges. I am told by vessel men that the additional cost of transporting coal up the narrow rivers in deep-draft vessels amounts to somewhere from

3c to 5c per ton, due to towage charges, delays, etc. A lake vessel has to earn its profit on investment in about eight months, and time is important. If a vessel is delayed in reaching the dock and discharging cargo, that may cut out one trip for the season, which means a good deal.

So far the transportation problem in Milwaukee has not assumed definite form. A commission has been appointed by the mayor to investigate the subject from a local and financial standpoint to determine whether it will be of benefit to Milwaukee to go into this scheme, which will involve the expenditure of some three to five million dollars, and careful investigation and study is demanded.

There is a marked difference in freight rates and unloading expenses in different parts of the rivers in Milwaukee. I made some hasty figures before coming here this evening, and find that the Pennsylvania Coal Company, whose yards are favorably located and which are equipped with modern coal-handling machinery claim that they unload anthracite coal at a cost of about 8c per ton, and bituminous coal at about 9¼c per ton. The North Side Fuel Company, which purchases coal through the Pennsylvania Coal Company, is located up the Milwaukee River, near the head of navigation. This company does only a local business, and consequently has not as complete an equipment of coal-handling machinery as the Pennsylvania Coal Company, which does a large reshipping business. The small company claims that it costs them 11c per ton to unload anthracite and 14c to unload bituminous coal. The freight rate to the docks of the Pennsylvania company is 35c per ton as against 45c at the North Side Fuel Company's dock. This shows the desirability of concentrating, as far as possible, the docks for handling bulk commodities, and making the unloading facilities as complete as possible, at least for through shipments. Of course, with local shipments, the cost of team haul must be considered; it may be more profitable to pay 10c extra on vessel haul, and carry the coal several miles nearer to the point of ultimate consumption, than to pay the additional cost of team haul.

A few years ago the U. S. Engineer Office at Milwaukee was called upon to investigate the cost of the passage of a lake vessel through a canal or a canalized river. The results obtained were based upon statistics from the "Soo" canal and also upon meager information of the time consumed by vessels passing through the Sturgeon Bay canal. Taking the cost per ton-mile of the deep-draft carrier on the open lake as unity, it was found that for the same deep-draft vessel passing through a canal without locks the cost was 1.46 and for the same vessel in a canal with locks, 1.61. For vessels of lighter draft,—say from 11 to 14 ft.,—the cost per ton-mile was found to be about 2.1 for open lake, 3.07 for canal without locks, and 3.26 for canal with locks. This estimate was

applied to a canal between Chicago and the Mississippi River, and to the barge canal from Buffalo to Albany. It was assumed that the average distance between locks was about 35 miles. The estimate was based on the relative time in hours that it would take a vessel to pass through a canal as compared with the same distance in the open lake, assuming that the cost of haul was a direct function of the time consumed.

Mr. Symons: The statement was made this evening that the value of land occupied by a freight car has been estimated at $20,-000, the idea doubtless being to convey the impression that on account of the great value of this land it should be devoted to other purposes.

A modern freight car is about 40 ft. long and 10 ft. wide; therefore the area of ground space which it occupies is about 400 sq. ft. If estimated at $20,000, this would be about $500 per sq. ft., which at first thought is rather an unusual amount of money to have invested in land used to support a box car. One might think this could be better utilized for a mansion or a fine office building, but we must first consider why this land is of such great value. On reflection or analysis it will be found that the principal reason lies in the fact that the land *is* covered by a box or freight car, and that if it were used for any of the other purposes its value would shrink to that realized for land in the suburbs of cities, for various reasons.

First, if the freight tracks, or any considerable portion of them, were removed, it would detract from the value of the land which they now occupy, and materially interfere with the prosperity of the city. People of wealth who are able to purchase land at the price at which this land is estimated, would not live in that part of the city under any circumstances if the railway tracks were removed.

Second, people in the middle class of life or the poor people could not afford to buy the land.

Third, factories or industrial concerns would not think of locating there if the railway tracks were removed.

Therefore, while the land is seemingly a very high priced support for a box car, yet an analysis will show that it is the freight car's presence which gives it this value. It is the freight-car tracks in the heart of the city and commercial centers that make live commercial centers and provide the means for building the beautiful homes that are properly located on the outskirts of the city. If these tracks were removed from Chicago, and the alleged smoke nuisance entirely abated, then Chicago, instead of growing to be a city of 13,000,000 inhabitants, as has been predicted by good authorities, would, in my opinion, at once begin to retrograde, and the population would gradually decrease until we would find our-

selves just an ordinary town with 1,000,000 or possibly 500,000 people, and with not much life or vitality at that.

This question of having freight-car tracks and freight terminals in the center of a large city is in keeping with the progress of the times. Years ago it was the custom for the country merchant to stock up once or twice a year. Later on, as the country developed, and means of transportation became improved, he went to the large trade centers and replenished his stock three or four times a year. But for some years past a large part of the necessities of the people which come from a large center of distribution have been ordered by telegraph or telephone. There are thousands of freight cars sent out of Chicago almost daily containing shipments of goods ordered inside of the preceding twenty-four hours. Merchants living ten, twenty, fifty, or two hundred miles from Chicago order less than carload lots of goods by telephone, on condition that they will be delivered at their town during the night, so that the goods will be in their store ready to deliver to their customers early the next day. So, to consider moving freight tracks and yards outside of the city to the present belt lines or to a new one beyond the limits of the present one, would be to consider taking action that would be not only detrimental to Chicago's interests, but from the standpoint of the city's commercial prosperity it would be suicidal in its effect, and result in driving millions of dollars worth of business elsewhere. However, I do not think the idea will be given serious consideration by either the transportation companies or commercial interests. One of the grandest tributes that can be paid to the railways and commercial interests of Chicago is the fact that a piece of ground about 10 ft. by 40 ft., large enough to support a freight car, is estimated to be worth $20,000.

Mr. Fixmer: In connection with moving the railway freight terminals out from the center of the city, is it the idea to utilize the Illinois Tunnels to take freight from outlying stations direct to the warehouses, and vice versa? We know what the conditions are today in connection with the various freight stations, the team haul across the city, and the consequent delays and congestion, which affects all other traffic. The ideal solution would be to eliminate all team haul from the streets. Surely it is possible for the Illinois Tunnel Company to increase its tonnage to handle this traffic and also to develop a system of lighters. The ideal that the author has made plain is to eliminate as nearly as possible all team haul in Chicago, because that is the most expensive form of transportation.

L. C. Fritch, ASSOC. W. S. E.: I have read Colonel Zinn's paper carefully and agree with his plan of location for harbors,—namely that there should be outer harbors and that the Chicago River should be utilized to its utmost extent.

In connection with the railway terminal facilities, there should

be a harbor located so that all railroads would have access to it over a belt line owned by all railroads, in order that all roads may have equal facilities to reach the docks and wharves.

J. W. Alvord, M. W. S. E.: Although not presuming to be an expert on transportation matters, I cannot refrain from endorsing the views of Lieut. Col. Zinn, as expressed in his paper, as they are in entire accord with my own ideas heretofore expressed before the Chicago Real Estate Board and elsewhere. It does seem to me that the author has struck at the roots of the subject in presenting so admirably the fundamental principles underlying the location of a harbor for this city, principles which have not been adequately emphasized in the harbor reports or harbor literature we have developed of late years, and I have followed it somewhat carefully.

I have always believed that there are some fundamental principles involved in the creation of ports and facilities for commerce, that are simple and understandable, and in the discussion of the harbor question in Chicago these simple and fundamental principles have been somewhat overlooked, or even beclouded by the presentation of a mass of perplexing detail, valuable in itself, but not elminating the main issue. One of the important and fundamental principles to be observed, it seems to me, is:

> *That a harbor or port is an economical junction point for traffic interchange or distribution of sea or lake borne commerce with land carriage, and its effectiveness is primarily dependent on this fact.*

Necessarily, at such junction points, population centers spring up, manufactures find location for economic reasons, and storage and exchange facilities are necessitated.

It is obvious, if a harbor or port is a *junction point,* economic handling of freight requires close proximity of ship to car, with ample basin room, freight yardage, ready access, and all up-to-date mechanical contrivances for the transfer. If this is true, it is idle to talk about lighterage systems, wagon transfer across congested streets, or outer harbors barred away from rail freight yards and terminals by miles of high-class business and semi-business property.

A proper harbor for Chicago needs to be connected directly with ample rail freight yards, and all the necessary facilities, and this should be the case with every important rail line leading out of Chicago, and not with one or two lines, or with one or two inefficient switch tracks, as is proposed by our present outer harbor proposition. Nor is the local freight distribution, or the fruit or lake passenger business widely different from heavy or through-freight in this respect. What well serves the one well serves the other.

The modern commercial world is now accustomed to quick freight transportation from the factory to the consumer's ware-

house, and if sea-borne freight intervenes, it must be unhampered by more than two handlings, one at each port, and these of the most advantageous and economical type.

Now, the city of Chicago, by reason of its own growth and necessities, began about ten or twenty years ago to "choke itself to death," as far as lake-borne commerce is concerned; that is to say, it gradually allowed obstacles to the quick connection of the lake-carrier boats with the railroads, in the shape of bridges and bridge-closing ordinances, lack of depth, width, swift currents, tunnels, and other inconveniences, which greatly increased the cost and diminished the facility of transfer.

Eight or ten years ago we awoke to this condition of affairs and began to remedy these evils in the way of a wider and deeper river, better bridges and turning basins, the removal of obstructing tunnels, and like inconveniences. In this good work the Government of the United States, the Sanitary District, and the city co-operated, for a time, to good purpose. The inspiration of a Waterway to the Gulf was still in the air, and a continuing policy of some definiteness was still before us. But a change came over the spirit of our dreams. The Sanitary District found river improvement burdensome. They began to realize, what I believe to be a fact, that sanitation alone would exhaust all their resources for the next twenty-five years, and improvements jointly for commerce must not divert them from their real responsibilities.

Then harbor enthusiasts demanded a lake front harbor on the South Side between Thirty-ninth street and Grant Park, and the inferential abandonment of the river as a gateway by the closing of the bridges of the South Branch of the river. Then came our harbor commission, and much good and profitable study and discussion on traffic statistics, European harbors, harbors and commerce in general, and finally the location of a local freight harbor, which, in my opinion, is to be located in a questionable manner so far as an ideal *junction point* is concerned. Certainly it can be safely said that the local outer harbor to the north of the river mouth is still farther away from any real rail facility than anything which has been tested or found practicable so far in the history of this city.

Is it cheaper to bring the railroads through the heart of the city to a lake harbor, upon ways yet to be created, or bring the ships through the city upon existing channels to the railroad freight yards in the rear of the city as we have always done? This is a fair question; it seems to me it is the main question, and I have watched in vain to see it properly studied and discussed. It is the real question which divides opinion in Chicago today upon the harbor question.

Those who believe a harbor in almost any location is useful, or who believe the railroads can readily find their way to the lake

front, are in favor of a lake front harbor and closing the river bridges, and those who believe the main transportation of freight is now in the hands of the railroads and who believe the lake-carrier boat must come to the railroad freight yard, believe in an inner harbor and the open river door.

I am of the opinion, largely as a matter of instinct, that the lake-carrier boats, both passenger and freight, must come to the present railroad facilities both inside and at convenient points both west and south of the heart of the city. I am open to conviction, but I should like to see this particular question analyzed before seeing our city commit itself to any course of action such as is involved in the $5,000,000 project now to be voted upon. Our present harbor commission has my entire confidence, but has it been asked to take up this general question, or has its work been confined to the engineering design of piers in the lake at a particular point? I think it should be given a chance, first of all, to study the greater problem before us before being charged with designing piers or breakwaters.

Railroad men who are in a position to know, tell me that the modern railroad problem is in keeping up with the demand for high-cost terminals, and especially freight terminals. One has only to look at the map of Chicago, showing the miles and miles of freight-yard tracks, and the miles and miles of switch tracks reaching every factory and warehouse, coal yard, or elevator, to appreciate what it would mean to get ample freight yards and rail facilities through the immensely valuable business and semi-business district of this city to any lake front location reasonably convenient to the heart of the city. Property is too high to think of such a thing. Such facilities must of sheer necessity go to locations where they will not be loaded with such heavy fixed charges.

But it is said we cannot endure the bridge nuisance, and to create an inner harbor west of the city would be intolerable. It must be admitted that we must go to some expense and some inconvenience wherever a harbor is created.

We are planning a subway system, which, when completed, will, I hope, carry all the elevated and surface cars under the river, in and out of the central district. Only one or two important trunk railroad lines now cross the river in the heart of the city. Were these carried under the river rather than over, all serious rail crossing of navigable channels would be dispensed with. More of our important traffic streets from the loop district to the north and west sides could profitably be carried under the river in tunnels, as suggested by the author. It is conceivable that, in ten years of progress, three-quarters of the traffic now carried over the bridges might be transferred to subways. This has happened to the New York ferries, and is now happening in Boston and Detroit.

It has always been my thought that some day, when the

economic time arrives, there would be not only a subway for surface and elevated traffic, but a second and outer loop, connecting all the great railroad stations, and, by inclines, their outgoing lines, so that in the future electrical suburban service trains might proceed around such a loop and discharge the passengers at any of the principal railroad stations, or at transfer points to the inner loop. Such an arrangement would further free the river and present harbor from traffic incumbrance and give it enlarged facility as a channel of entrance.

The South Branch of the river will unquestionably have to be widened to 200 ft. in its narrowest part, with 21 ft. depth,—this as a sanitary as well as a commercial measure. West of Bridgeport and between that locality and Summit particularly, at and beyond the city limits is comparatively open country where a long shipping basin could be excavated cheaply in easy clay soil. Ample slips leading out of this basin would afford quick and convenient transfer from rail to car, and from car to rail, connecting with several of the belt lines and some of the trunk lines. The Chicago Sanitary and Ship Canal affords, according to our waterway authorities, future possibilities for a lake and gulf commerce. It will, in time to come, connect us with Mississippi River traffic, if no more. A belt railroad, such as the author says the railways are now considering, would directly connect this inland port with every rail line in the city, and indirectly with every switch track and warehouse, as well as with all other harbors, manufacturing centers, and trackage in the Calumet region, at Indiana Harbor and Gary. A system of internal barge traffic might possibly be accommodated by the Drainage Channel, the Sag canal, and the improved Calumet River as far east as Gary, but these points, of course, may be better reached by the lake direct.

Modern and up-to-date mechanical appliances for loading and unloaling ships to cars should be installed as fast as needed, but no faster. Warehouse and elevator sites, coal yards, and dockage could be provided for on a liberal scale, for the future Chicago. A similar harbor in Calumet Lake such as is outlined by the harbor commission is also indicated as a feasible part of such a general plan.

In pursuing such a general plan as this, it seems to me that we are but following out the instincts of a generation past of practical minds who have wrestled with this problem. The vast vested interests in dockage, manufacturing enterprises, warehouse and lumber, coal and grain, and other interests which now cluster along our rivers, and especially the west fork of the South Branch, did not locate there by chance, but by foresight and wisdom, the best wisdom of the day and age, following the path of least resistance, which is also the path of economy in industry. To in any way wipe out, or attempt to wipe out this effort, to suggest that

we close off this vast hive of human endeavor, is absurd and visionary. As the author well says, we might as well ask the Pennsylvania and Illinois Central railroads to take up their tracks and move out of town. The district along the South Branch of the river will always remain an industrial center, and that part of the main river and South Branch leading to this center and to the waterway beyond, will have to become a doorway and portal. We might as well recognize this fact first as last, and get the people and the traffic underneath this portal by tunnels and subways, rather than over it by clogging and numberless bridges.

An improved river entrance, a widened South Branch, and a new port beyond Bridgeport, with supplementary ports at the Calumet, Indiana Harbor, and Gary, all in connection with the present and future proposed belt line railroads, it seems to me solves the fundamental proposition of a *junction point* between car and boat, with quick mechanical transfer appliances to make such junction point effective. In other words, bring the boats to the railroads as we have always heretofore done, and do not compel the railroads to attempt the impossible problem of attempting to cross through the heart of a great city with freight lines, where land values are all but impossible, where congestion is already a problem, and where even room for passenger terminals is already a most serious and perplexing problem for the railroad companies to finance.

I am aware that the present outer harbor proposition is intended only as a beginning, and that it is primarily intended to relieve the congestion at the mouth of the river of package freight and passenger (particularly summer) travel. I cannot help but feel, however, that the fundamental principles that the author has pointed out in his paper, apply equally to this problem as to that of main terminals and ports for coarser freight.

The passenger travel and the package freight at present centering at the mouth of the river do so because it is the most effective junction point available. The fruit from Michigan seeks the nearest landing to South Water street. The thousands of summer passengers to points on the lakes seek the nearest junction point to the elevated and surface cars to carry them to their homes or to the railway stations. To interpose an average of a mile or a mile and a half more distance, and a transfer between this traffic and its destination, is to greatly increase the cost of this transportation and interpose an intolerable burden of delay and inconvenience daily to thousands of people and hundreds of tons of freight. I speak on this point with some experience, because for the past dozen years I have been a constant summer traveler on these boat lines to my summer home in Michigan. I venture to predict that, even if the outer harbor piers are built north of the river mouth, as proposed, the summer passenger boats and fruit trade will con-

tinue to center as far up the river from its mouth as bridge restrictions and bridge-closing ordinances will profitably permit, and that the new harbor will only be used in the near future by the few lines that are actually crowded out of the main river by the physical impossibility of finding room to land.

I cannot help but believe, with the author, that the relief afforded by subways and tunnels will permit us to utilize the river for river traffic to a greater extent than has ever been deemed possible. We have a bridge-closing ordinance that is a relic of the days when our river was crowded with sailing vessels, a condition I well remember. What inconveniences would be the result of an enlarged privilege to the river traffic even now is an open question. Certainly with the completion of more tunnels and subways, the river should be entirely freed from its fetters in this regard.

In an address on this subject, which I had the honor of making before the Real Estate Board of this city in March, 1908, I made the following statement with reference to the proposition to create an outer harbor on the South Side lake front:

> "My objections to a harbor on the lake front would be that it would turn the city upside down and inside out, and everything would have to be rearranged at tremendous expense in ways that are hardly capable of being foreseen or thought of."

While this remark has somewhat less force as applied to the present proposition, it still looks to me as if this city was about to engage in an enterprise that is in violation of basic principles, and which, if it does not result in serious financial loss, will at least cause useless depletion of our present scanty and needed resources for an enterprise whose utility is at best questionable.

A. Bement, M. W. S. E.: Everything considered, this paper, in my opinion, is one of the best, if not the best, discussions we have had of the Chicago harbor, or, the author would term it, the water terminal.

The treatment accorded the subject is broad and comprehensive. The fact that the author has not been a resident of this community for a long period may have had some bearing on the presentation of the scheme for interchange of rail and water freight, a matter beset with great difficulty, as it requires coöperative action on the part of the railroads, which, if not impossible, would certainly be difficult to attain. The scheme of an outer belt railroad for interchange of through-freight between roads is, of course, desirable, and I do not understand that there is any question about the value of it. But the natural competition between the different roads appears to make it impossible for them to get together on any such enterprise, notwithstanding the fact that it may have universal merit. In saying this, however, I want it distinctly understood that criticism of the railroads is not intended. In my opinion they are

doing the best that they can, but the problem is one beyond any remedy in the possession of the roads, and demands the assistance of independent influence.

Thus we are compelled to consider the Chicago plan, and to note again that it offers no help in industrial problems. It is well that we have a serious, in fact most serious, defect of the plan indicated to us from such a disinterested and impartial source. It is helpful to us that the author has called attention to an industrial requirement, the recognition of which carries with it criticism of the provisions and status of the plan.

The Chicago plan has been styled by Colonel Milton J. Foreman a "front yard" plan, in its failure to provide for any but the exterior ornamental features noted. Mr. Wm. B. Jackson has called attention to the necessity of giving the plan a legal status, making its provisions subject to compassing fulfillment, which is certainly a necessary measure if we are to have a comprehensive development of the city.

It would appear that the author does not consider docks at the mouth of the river to be desirable. In this respect his views are at variance with those of the majority of the people who have considered the matter. Personally I think that these docks are really the only things that are an absolute necessity at the present time.

It may appear to some that those people who have considered the matter, in the past, have failed to obtain as broad and comprehensive a view as the author. This is undoubtedly true in some respects. It is, however, a fact that some of the agencies which have had the matter under consideration, have considered the problem from the standpoint of immediate results. They have proposed to make such connection with railways as might be necessary, by means of car lighters, in view of the impracticability, under existing conditions (and which conditions are likely to continue in the same state for some time in the railway situation) of attaining more adequate connection.

C. R. Dart, M. W. S. E.: It may not be amiss, in connection with this paper, to state the number of bridges spanning the rivers of Chicago.

The main Chicago River has at present five bridges with a possibility of the addition of three more. From the forks to the drainage canal at Robey street are twenty-two bridges with several long stretches unbridged which will require spans in the not far distant future.

The Drainage Canal now has fifteen bridges, ten of which are east of the junction of the Calumet-Sag Channel. Present total on river and canal, forty-two.

The North Branch of Chicago River to Belmont avenue is spanned by eighteen bridges.

The Grand Calumet River has thirteen bridges between the lake and the forks.

The Little Calumet River has seven bridges from the forks to Ashland avenue.

In going by way of Chicago River from the lake to the junction of the Calumet-Sag Channel and the Main Drainage Channel, thirty-seven bridges must be passed. In going from the lake to the same point by way of Calumet River and the Calumet-Sag Channel, at least forty-two bridges must be passed. The number will be increased in the near future on both routes above mentioned.

Regarding the use of the Chicago River as a harbor in the business district, on the main river and South Branch, bridges occur at practically every street and only the smaller uneconomical carriers can go to dock between these bridges. The bridges are now farther apart south of Twelfth street, but the dock property is owned by railroad companies, and in order to reach this locality eighteen bridges must be opened. Nor is it improbable that, as the business district expands, more bridges will be added until the condition of the river becomes the same south of Twelfth street as now in the downtown district.

It has been suggested by the author and by others that tunnels can be placed under the river, thereby making bridges less necessary. Tunnels undoubtedly will be built in connection with subways, but such tunnels will be available for subway traffic only, and on account of the resulting inconvenience to surface traffic, it is questionable whether the public will sanction the removal of any existing bridge. Even if tunnels are built for team traffic, the length of approaches and the necessary long descent and long wearying climb in passing through will make them very unpopular. Tunnels can hardly be built for surface and subway traffic at the same street and certainly not to take elevated railroad traffic also. Chicago once built two tunnels and turned them over to the traction companies because of their little use by the public: The time seems very far distant, therefore, when the main traffic across Chicago River will be carried through tunnels so that the bridges can be removed as unnecessary, or so that their frequent operation will not be objectionable.

As traffic in the river increases because of improvement in river conditions, the interruptions due to bridges will correspondingly increase, and it will be unlikely that the public will entirely give up the closed bridge hours during the time the workers and business men are going to and from their work or place of business, and when they have little patience with conditions that continually cause them to be behind time in reaching their destination.

The writer has not intended to argue for or against either an outer or an inner harbor, but wishes to state certain facts as they appear to him. Attention is called, however, to the 1909 report

of the Chicago Harbor Commission in which are shown layouts of the principal ports of the world. It may be noted that at *none* of these,—at Liverpool, Glasgow, London, Antwerp, Havre, Hamburg, nor at any great seaport,—are bridges permitted that must be opened to allow a vessel to enter the harbor, nor are they permitted at our own great seaports. We find them only at our Great Lakes ports, where the size of the carriers is outgrowing or has outgrown the conditions under which the commerce developed.

Closure.

The Author: In the matter of transportation, effort should be made in every direction to reduce the cost. The cheapest means of getting a shipment of merchandise from consignor to consignee is to move it all the way by water, if possible. If the consignor and the consignee are on the water, they have the cheapest form of transportation. If they are not on the water, then we must ascertain what form of transportation will be the cheapest for them. In Chicago, the congested freight district today is within the inner belt line. The railroad companies have recognized the fact that the time is coming, and very soon, when, in order to conduct their business properly, they must reduce congestion by keeping out through-freight.

Mr. L. C. Fritch, the Chief Engineer of the Chicago Great Western Railroad Co., presented a paper to the Traffic Club some two months ago, which is printed in the *Way Bill,* explaining his idea—and I assume the idea of his association—as to a belt line. In my paper I have taken Mr. Fritch's idea on that, and add, that in combining the waterway business with the rail business the principle, that the through-freight must be kept out of the city of Chicago, must be followed. This means that the transfer or commercial harbor must be located outside of the congested limits. As for the local-freight, it of course must come into the city and be delivered, by water or rail, as near as possible to the location of the consignee.

These are the general principles, and I do not see how we can get away from them. However, I believe that the difficulties which have been mentioned tonight by each of the speakers have originated in applying these principles. Take, first, the delays caused by open bridges. It has been said that the waterways should be used to their fullest extent for the transportation of freight; but the business of Chicago which demands the crossing of the streams is in conflict with the business that goes through the bridges, and it seems to me that the waterway business is the most important to the city of Chicago.

A daily record is kept of the number of openings of the bridges, and the period of each opening. The average length of time the bridges are kept open is about three minutes; the average number

of times the bridges are open varies from twelve to twenty per day during eight months of the year, for during four months of the year the river is closed to traffic. Also, during four hours of the daylight each day the bridges are closed,—two hours in the morning and two hours in the afternoon. In other words, navigation has about twelve hours of daylight for eight months in the year. Yet many complain because of having to sit in a trolley car three minutes to wait for the passing of a ship that saves them $2.00 on every ton of coal they burn, because that ton of coal comes by water from Buffalo at 40c, whereas if it were shipped by rail the transportation charge would be $3.50 per ton. Investigate these figures for yourselves and see whether it is cheaper to open the bridges or close them.

The Mayor of this city has said that the construction of subways will begin the first of April. With the completion of the subways we will go under the river. Residents of Evanston will reach the center of the loop district from that suburb within twenty minutes, and not know that the river is there. The boats will be moving over their heads. I hope to see the day when boats will be going so frequently up and down the river, on account of business being so great, that the bridges will have to remain open.

Think of 13,000,000 inhabitants! Chicago has more than $2,000,000 inhabitants now. Where will the future 11,000,000 be located,—in Indiana or Illinois? Where will be the center for the transaction of business? In my opinion it will be at Gary, or possibly Hegewisch. We must wipe out the state line; all that territory is subsidiary and tributary to Chicago. It belongs to Chicago.

Within the memory of every one present,—within ten years, we will say,—the sandy wastes along the Calumet River have been built up, and 7,000,000 tons of freight, worth anywhere from $5.00 to $40.00 per ton, is moved out of that district annually. Now do you think the loop district of Chicago is doing that business? No! The office men are handling it and their offices do not need to be in the loop district; they might just as well be at Gary. Land in that locality is now selling at $1,000 per acre, and offers have been refused of $3,000 per acre. Twenty-five years from now that whole region will be covered with factories of all kinds. The Baldwin Locomotive Works recently purchased a large piece of property in East Chicago, and a subsidiary company, called the Philadelphia Syndicate, obtained a piece of property next to it and divided it into lots to sell to the people who are going to work for the Baldwin company. Some of you may not know about that large factory there that is going to remove the tin from tin cans? There is also a company called the Air Products Company. When we asked them how many tons they shipped by rail, the reply was, "The atmosphere belongs to us." They make their products out of the atmosphere.

This brings us to the question of the Sag channel. Of course we will use that channel, but the Calumet River has bridges. Boats that go through the Calumet River, the Sag channel, and up into the Chicago River will have a longer and more expensive trip than to come in through the Chicago River. The center of population is moving in the direction of the Calumet region, and it is quite probable that many of the future 11,000,000 people will settle there, so there will be the same number of bridges on the Calumet River and more people crossing them than are now crossing the bridges at Twelfth Street, Lake Street, State Street, or elsewhere on the Chicago River. Conditions then on the Calumet will be the same as they are today on the Chicago River. So let us use every waterway—every one of them. I shall be glad when the Sanitary District completes the Sag channel and opens it for navigation.

A railroad man was asked what it would cost the citizens of Chicago to put in fixed bridges. He based his estimate, I think, on 2,500,000 tons of freight. Suppose that every ton of that freight had to be landed at the mouth of the river and transported by teams, cars, or lighters throughout the city. He said every carload would cost about $24.00, or, we will say, about $2.00 per ton. Multiplying that by 2,500,000 gives $5,000,000,—the cost to the citizens of Chicago annually to close the Chicago River under present conditions. As explained, there is now an artificial condition at Chicago, because the railroad companies control the movement of package freight. If this control were not exercised today, and freight could be shipped freely by water from Chicago to other points on the lake, it could be handled at about one-sixth of the present cost.

In regard to connecting the outer harbor with the railroads, a gentleman of this city asked me recently if I knew that there was an embargo on the C. & N. W. Ry. on the north side of the river. I said I did not, and asked what he meant. He replied, "Today the Northwestern Railroad will not deliver any freight on the north side of the river." What will happen to your harbor when the Northwestern Railroad cannot take the freight? One gentleman said that the State Railroad and Warehouse Commission had the right to compel connection between railroads. I think there should be a law compelling the connection of railroads with water transportation. This will require an act of Congress, and it will be a long time before Congress passes such an act.

President Armstrong: Is there not a law in existence, compelling all common carriers to prorate?

The Author: No, but I wish there was. One sometimes ties down his thought by improper use of words. The word *harbor* is unfortunately used by many to mean a single locality and place—a circumscribed area of some kind. The sailor employs that term when he means a place where his ship can rest in safety from the storms of the sea. That is the definition which I prefer.

Some think of a harbor as a place where boats are unloaded, but this is not necessarily the case. If we can substitute the term *water terminal* for the word harbor, we will get away from the idea that we must bring everything together. A water terminal is a place where a boat can unload or receive a cargo. The word harbor may create a wrong impression. Instead of the term industrial harbor or commercial harbor, I would use the term transfer harbor or transshipping harbor. A transshipping harbor means transferring from rail to water or vice versa. In transshipping coal from water to rail, concentrate such facilities, because that is a place of transfer, and such concentration will undoubtedly reduce the cost of transshipping. But if by the word harbor you mean a place to unload all package freight intended for the entire area of the city, then that is something that is entirely wrong. The railroad companies do not attempt to do that. They send their spurs in all directions and try to reach every shipper of any magnitude; they try to reach every consignee; they will build him a spur track if his business seems to warrant it. One of the present troubles in Chicago is that there are too many spur tracks; many of them are not needed now, and the railroad companies, by an adjustment of their local delivery tracks, could dispose of a great deal of this land which is worth $20,000 per space occupied by a freight car.

APPENDIX.

A PUBLIC NOTICE OF A HEARING BEFORE THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS AND A REPLY THERETO BY THE CHICAGO RIVER AND TERMINAL ASSOCIATION.

Chicago, Ill., March 1, 1912.

PUBLIC NOTICE.

To Whom It May Concern:

1. A public hearing before the Board of Engineers for Rivers and Harbors will be held in Room 508, Federal Building, Chicago, Ill., at 10 a. m., Wednesday, March 27, 1912, at which hearing all persons interested will be given an opportunity to present their views upon the subject of the improvement of harbor facilities for Chicago and adjacent territory.

2. While oral statements are of value, all important arguments and statistics should be submitted in writing (in duplicate), in order that they may become of record in accordance with law.

3. The River and Harbor Act of Congress, approved March 3, 1909, containing an item requiring an examination and survey of:

> "harbors and rivers at or near Chicago, Illinois, including Chicago Harbor, Chicago River, Calumet Harbor, Grand Calumet and Little Calumet Rivers, Illinois and Indiana, Lake Calumet and necessary connection with Calumet River, and the lake shore from the mouth of Chicago River to the city of Gary, Indiana, for the purpose of reporting a plan for a complete, systematic and broad improvement of harbor facilities for Chicago and adjacent territory."

4. The United States engineer officer to whom the duty of

making the above-mentioned examination and survey was assigned, has made a report containing a number of recommendations, which in brief are as follows:

(a) A commercial harbor for the transfer of lake and rail freight should be constructed jointly by State and United States authorities at some point on the lake shore in the vicinity of Gary or Indiana Harbor, Indiana.

(b) A commercial harbor for the transfer of canal and rail freight should be constructed by State or municipal authorities on the Main Drainage Canal of the Sanitary District of Chicago at some point in the vicinity of Summit, Illinois.

(c) The present "outer basin" of Chicago Harbor and the northerly breakwater should be maintained for an anchorage basin and harbor of refuge for lake carriers.

(d) The Chicago River from its mouth to Belmont avenue on the North Branch (including North Branch Canal), to Ashland avenue on the South Branch, and to the railroad bridges near the Stock Yards at the end of the South Fork, South Branch, should be provided with navigable channels not less than 200 feet wide and 21 feet deep.

(e) Turning basins should be constructed at the junction of the North and South Branches of the Chicago River and near Belmont avenue on the North Branch for lake carriers of the largest dimensions.

(f) The West Fork of the South Branch of the Chicago River should be provided with a channel not less than 150 feet wide at top, 100 feet wide at bottom, and 12 feet deep from Robey street to a point 1,300 feet west of South Kedzie avenue, for use by barges, lighters, etc.

(g) Center-pier bridges, closed bridge hours, and the towage ordinance are unnecessary obstructions to navigation.

(h) The City of Chicago should provide, own and operate public docks at suitable intervals along the Chicago and Calumet rivers for shipment and receipt of local water borne freight.

(i) The outer harbor at South Chicago, known as "Calumet Harbor," should be maintained.

(j) The Calumet River from its mouth to the "Forks" should be provided with a navigable channel not less than 200 feet wide and 21 feet deep, with the turning basins now provided for by law.

(k) The Grand Calumet River should be provided with a navigable channel not less than 150 feet wide at top, 100 feet wide at bottom, and 12 feet deep, from the "Forks" to the Indiana Harbor Canal, and with three turning basins, for use by barges, lighters, etc.

(l) The Little Calumet River should be provided with a similar channel from the "Junction" to Stony Creek.

(m) A breakwater should be provided to protect the entrance to Indiana Harbor, Indiana.

(n) The Indiana Harbor Canal should be maintained with a width of 200 feet and depth of 21 feet.

(o) The municipalities along the Grand and Little Calumet rivers and the Indiana Harbor Canal should own and operate public docks at suitable intervals along those waterways for the shipment and receipt of local water borne freight.

(p) No improvements in the waterways at Chicago or adjacent territory other than those specifically mentioned above are either necessary or desirable at the present time.

5. The Board will hear statements upon any or all of the above matters, or upon any others which properly pertain to the

above-quoted item from the River and Harbor Act of March 3, 1909.

6. Further information as to this hearing may be obtained upon application to this office. George A. Zinn,

Lt. Col., Corps of Engineers, U. S. Army.

Chicago, March 25, 1912.

To the "Board of U. S. Engineers for Rivers and Harbors."

Gentlemen: In compliance with the suggestion contained in the public notice issued from the U. S. Engineer's office by Lieut. Col. George A. Zinn on March 1st last, the undersigned hereby submit—in duplicate—an analysis of the various recommendations contained in Col. Zinn's epitomized report, commencing with (paragraph 4) of the said public notice.

This analysis is not presented in any spirit of political antagonism or prejudice for or against the harbor policy which the city authorities have decided to adopt, contingent upon the sanction of the city's electorate, which policy differs entirely from that recommended by your engineer in charge.

As practical men, whose lives have been identified with the transportation and handling of water-borne freight, and the terminal facilities connected therewith, we herein endeavor to show to your board what the experience of years has proven to be the most profitable method of harbor construction, and which, in our judgment, will best conserve the requirements of all those interested in the commercial development of a great sea or lake port.

In conclusion, gentlemen, we wish you to ever bear in mind that the endorsement appended to this analysis is due primarily to the essential necessity in any harbor of eliminating control of the water front, and the appurtenances and approaches thereto, by private or quasi-public interests, experience having proven that under such control the landing and storing charges imposed upon the cargoes of independent carriers are so high as to nullify all the economies derivable from the lesser cost of water-borne transportation, as compared with other methods.

Respectfully submitted,

Chicago River and Terminal Association.

Paragraph 4.

Section (a)—While appreciating the value of the recommendation contained herein, courtesy demands that we refrain from commenting upon a project which must be decided by the citizens of the State of Indiana, which it directly affects.

Section (b)—The vicinity referred to in this section is unquestionably the ideal location for a great commercial harbor.

Herein opportunities are presented not contained in any other section of the port.

Within an area consisting of a mile in length, and 1,000 feet or more deep, on either shore of the Drainage Canal, could be constructed a commodious harbor terminal that would suffice Chicago's present and prospective commerce for twenty-five years hence.

Such a terminal in our judgment should be acquired, equipped

and operated by the State, that the interests of interior towns as well as the port may best be conserved.

This could be accomplished expeditiously and economically. The realty along the banks of the canal, being public property and unencumbered by any structures, is all ready for building upon, and much of the material used in concrete construction work is in the immediate vicinity. Thus the total cost of all the essentials, which includes bulkheads, seawalls, slips, roadways, storage warehouses, trackage, mechanical freight handling appliances, etc., would be far less than the cost of the outer harbor as proposed by the local authorities, viz.: To construct piers on the lake front, north of the entrance of the Chicago River, where but one railroad connection can be made, and that one utterly inadequate to supply the demand that must necessarily be made upon it, if the rivers were closed by fixed bridges and all vessels compelled to use the outer piers, while the resultant efficiencies and economies that would accrue by the adoption of the U. S. Engineers' plans are so immeasurably superior to this and all others that they admit of no comparison.

Section (c)—The necessity for this recommendation is obvious to all who have to use the harbor for the purposes enumerated, and in our judgment any encroachments thereon, which would tend to lessen the present navigable area, would be a menace to navigation.

Section (d)—The channels embodied in this recommendation are the keys to the entire problem of—What constitutes the most perfect plan "For a complete, systematic and broad improvement of harbor facilities for Chicago."

There is not an interest within the city limits but what will be affected to a greater or less extent by the acceptance or rejection of this recommendation.

The channels with which it deals are the natural ones, upon the banks of which the city was built.

These arteries of commerce reach north, south and west, far into and beyond the city limits, and upon either shore innumerable interests have been established, representing in the aggregate an investment of many millions of dollars.

These streams with their present width and depth were amply sufficient in the past to accommodate the then existing type of vessel.

Modern commerce, however, demanded a larger and more economic type, to accommodate which other lake ports have rapidly adapted themselves, foreseeing the advantages to be gained thereby.

With these streams improved, as recommended, they would be accessible to the modern vessel, and in so far as the south branch of the river is concerned, it must be improved to give ingress and egress to these modern vessels, that would logically be desirous of taking advantage of the greater economies offered by the recommended terminal at Summit or vicinity.

It would be a hard matter to conceive the loss which discontinuing the use of these streams for commercial purposes would mean to the city.

Long established business would be compelled to remove their plants, or would be abandoned. Realty values would depreciate to such an extent that they would not be worth the taxes paid upon them.

The building materials, coal, lumber and other interests that

are handling like coarse freights, which are now located in the best available centers of distribution, if compelled by the closing of these channels to remove to a more remote point, unaccessible by water, would add the additional cost of receipt and delivery to the price charged for their wares.

Taken from any viewpoint, the abandonment of the river or its folks would be a commercial calamity. *And if this is true, then the logical corollary is, that any project that tends to improve these same channels is a commercial benefit.*

Section (e)—This recommendation is an indispensible part of the general improvement and should be supported.

Section (f)—While agreeing with your engineers in charge, relative to the necessity of improving the west fork, as recommended in this section, we are desirous of taking advantage of the latitude which the words "not less" that prefixes the minimum dimensions given in this section, and respectfully request where it is possible this channel should be improved to conform to the same standard dimensions that apply to the north and south branches of the river. This would preclude the necessity of compelling the larger carriers to break bulk, which would be necessary to lighten her of sufficient cargo to permit her to reach her berth.

Section (g)—None can deny the truth of this assertion, therefore, the Chicago river being a navigable water of the United States, the question arises as to the right of the municipality to maintain the obstructions referred to, in violations of the United States Statutes governing such waters, either in the case of removing the center piers, or the ordinances which require the closing of the bridges during the prescribed hours, and compulsory towage, especially the latter, *which is a local tax upon commerce* and hence violates the Interstate Commerce Law, under the pretext of safeguarding the city's property.

Section (h)—The suggestion is good, as evidenced by the results attained in other ports, that own and control the water fronts.

As hereinbefore stated, private ownership, or the monopoly of the desirable water frontage by so-called "public utility corporations" precludes the possibility of competition by independent carriers.

Docks municipally owned and operated, open to all vessels without discrimination, encourage independent operators to compete, *and thus creates the best freight regulator conceivable.*

Section (i)—Comment upon this assertion is unnecessary to those familiar with the rapid development of this industrial section of the city. In our judgment, not only should Calumet Harbor be maintained, but developed to its fullest capacity, for if all present signs do not fail it will be taxed to its limit in the near future.

Section (j)—Should this recommendation prevail the benefits derived by local commerce would be incalculable.

It would give over five miles of a good navigable channel that would accommodate the largest type of vessels navigating the Great Lakes, and would be an incentive to the construction of a commodious harbor in Lake Calumet.

Many large manufacturing plants are already established upon the banks of this river, whose business alone would justify the cost of improvements, and the added depth and width would prove a great inducement to prospective occupants of the vacant territory.

Sections (k-l-m)—The recommendations covering these sec-

tions are in the interest of both commerce and navigation, and should be supported by both interests.

Sections (n-o)—In reference to the suggestions contained in these two sections, we take the same stand as in Section (a), and defer an extended comment, though heartily recommending them to the citizens of our sister State who are more directly affected, as being part of a great plan for the commercial development of a vast territory, that must allow no political divisions, or other artificial barriers to stand in the path of its completion.

TO SUMMARIZE.

In so far as these several recommendations affect the port of Chicago, and would tend to the immediate relief of the intolerable condition at present prevailing therein, we respectfully suggest that they be carried into effect in the following order:

BY THE FEDERAL GOVERNMENT.

Section (d)—Réferring to Chicago River, branches and tributaries.

Section (e)—Referring to turning basins in the Chicago River.

Section (f)—Referring to West Fork improvement.

Section (g)—Referring to center piers and adverse ordinances.

Section (i)—Referring to Calumet Harbor.

Section (j)—Referring to Calumet River improvement.

Section (k)—Referring to Grand Calumet River improvement.

Section (l)—Referring to Little Calumet River improvement.

BY THE STATE.

Section (b)—Referring to the commercial harbor at Summit, or vicinity.

BY THE CITY.

Section (g)—Referring to center piers and adverse ordinances.

Section (h)—Referring to public docks on river front.

APPENDICES.

No. 1—Official records show that the average time occupied, from the opening to the closing of a bascule bridge is 2½ minutes. Statistics also show that the detention of a surface car, or team going 3 blocks in the loop district equals 3 minutes on an average, or 1 minute to each block, and this is continuous during the business hours, while 30 openings of the bridges would be a larger daily average for 8 months of the year, which means a total of 1¼ hours per day, or 24 hours.

No. 2—We advocate the enactment of a law compelling all common carriers to prorate on an equitable basis—with all established lines of vessels, and independent carriers, operating upon the Great Lakes and connecting with waters beyond them, thereby assuring to the shipper a through bill of lading.

WIND PRESSURE AGAINST INCLINED ROOFS

H. P. Boardman, M. W. S. E.

Presented December 6, 1911.

INTRODUCTION.

Many experiments have been made in the last two centuries to determine the pressure exerted by the wind against surfaces of various shapes and sizes, but the positions of these surfaces relative to the ground and surrounding objects have not been sufficiently varied to exhaust the subject.

The experiments herein described, which were made under the writer's direction, were undertaken with the hope of shedding some light where uncertainty seemed to prevail.

Within a year after undertaking the teaching of graphic statics in the University of Nevada, the writer received a copy of a bulletin of the University of Illinois, by N. Clifford Ricker, on the subject of roof trusses. This bulletin contains a diagram comparing the formulae of various eminent authorities expressing the relation between wind pressure against a vertical surface and against roof surfaces of various inclinations. The comparative diagram shows curves for the different formulae all based on an assumed pressure of 30 lb. per sq. ft. against a vertical surface. For a roof inclination of 30° these curves showed normal pressures ranging from 23.8 lb. per sq. ft. for Duchemin's curve to 7.5 lb. for Müller of Breslau. At the roof inclination of 15° the normal pressure from Duchemin's curve was shown as more than seven times that indicated by the curve of Müller of Breslau. For inclinations steeper than 30° these two curves come closer together, until at 65° for Duchemin and 85° for Müller they indicate the full pressure of a vertical surface, 30 lb. per sq. ft.

A great proportion of buildings with large roof areas have roof inclinations less than 30°, so it is evident that in the majority of cases where an engineer or architect is called on to design roof trusses spanning considerable openings, there is a great uncertainty as to the correct value of one of the forces involved. On the diagram above referred to are shown three other curves lying for practically their whole lengths between the curves of Duchemin and Müller. Hutton's curve is next below that of Duchemin for most of its length and lies quite close to it giving from 70 to 90% as great pressure, and Hutton's formula for normal wind pressure has been extensively used in England and America. This formula is

$$Pn = P\left[\operatorname{Sin}\alpha^{(1.84\cos\alpha-1)}\right]$$

April, 1912

Where Pn=normal component of wind pressure in pounds per square foot against an inclined surface.

P=corresponding pressure in same units against a vertical surface.

α=angle of inclination of surface to the horizontal

Mr. Ricker in his article says that "Müller of Breslau is the greatest living authority on graphic statics and probably on the theory of bridges and roofs." Please note that Müller's curve indicates the lowest pressures of any given.

Mr. Ricker, recognizing the uncertainty regarding wind pressures, sensibly recommended for the time being a simple straight-line type of formula that deviates but little from Hutton's curve, but is much simpler to apply. This formula for the case of 30 lb. pressure against a vertical surface is

$Pn = 2/3\ i$ for $i < 45°$

Pn=30 lb. for $i > 45°$ and $< 90°$

where Pn is as described above and i equals inclination of roof to horizontal, measured in *degrees.* The writer has since been using these straight-line formulæ in graphic statics.

Strong westerly winds are of frequent occurrence in Reno during the spring and autumn months, and in 1908 the writer conceived the idea of the tests which were carried on by the civil engineering department of the University of Nevada in 1910 and the spring of 1911.

Before describing these tests and discussing the results, reference will be made to the tests made in England by Stanton and published in 1907, but of which the writer had heard nothing until the autumn of 1910, after the Nevada tests were well under way.

ENGLISH TESTS.

These English tests are described in Vol. CLXXI, *Institution of Civil Engineers,* entitled "Experiments on Wind Pressure," by Thomas Ernest Stanton, D. Sc., M. Inst. C. E. They form the second part of a series of experiments commenced by that author in 1902 at the National Physical Laboratory, England.

VERTICAL SURFACES.

In referring to former experiments, Mr. Stanton discusses those made at the Forth Bridge in 1882 and following years which showed a greater pressure per unit area on small than on large vertical surfaces. The Forth Bridge test surfaces were located comparatively close to the ground and to each other. Mr. Stanton's early tests were with small surfaces in an artificially produced air current in a closed channel, the surface being normal to the direction of air motion. These tests gave, for square and circular surfaces, $P = 0.0027\ V^2$ where P equals pressure in lb. per sq. ft., and V equals

velocity of air in miles per hour. Results obtained by other experimenters—Dines, Langley, and Froude—are given as ranging from $P=0.0029\ V^2$ to $P=0.0036\ V^2$ in the order named. In these small-scale tests Mr. Stanton found that while P was uniform for different sized areas of circular or square shape, it varied considerably (results not given) for surfaces of radically differing shapes, as circles and long rectangles.

His later experiments, on a larger scale, were conducted in the open air and at the top of a tower 50 ft. above the ground. The tower was of slender construction, similar to a steel windmill tower, and the surfaces exposed to test were held out to windward so as to catch the wind before it reached the tower. The results, when plotted on diagrams and reduced to an average curve for each case, were consistent for the three different sizes of vertical surfaces used, i. e., 5 by 5 ft., 5 by 10 ft., and 10 by 10 ft., the mean being $P=0.0032\ V^2$. This being a good check on the average results of Dines, Langley, and Froude, it may be assumed to give practically the correct value for k in the formula $P=kV^2$, and shows that for surfaces not differing radically in shape k is practically constant for different sized surfaces so long as they are *some distance above the ground* affording free passage for the air *underneath,* as well as on all other sides.

BRIDGE SURFACES.

Mr. Stanton also made tests with a model girder 29 ft. in length by 3 ft. 7½ in. deep, having a net area exposed to the wind of 56.3 sq. ft., and found $P=0.00405\ V^2$ per sq. ft. of net area, which equaled 53.6% of the gross area from over all dimensions. The proportion of net to gross area in the above girder is probably much higher than with most American bridge trusses, but when the exposure of both trusses of a bridge is considered, it will be seen that common specifications for wind force against bridges are not very wide of the mark. From the above formula for $V=100$ (miles per hour), $P=40.5$ lb. per sq. ft.

INCLINED ROOF SURFACES.

Mr. Stanton also made tests with inclined surfaces but these inclined surfaces were, like the vertical planes and model girder, supported 50 ft. above the ground. He used two symmetrically-inclined surfaces 8 ft. by 7 ft., and in his first series of tests they were as shown in sketch (Fig. 1), pressures being measured on windward slope at inclinations 30°, 45° and 60°.

The results of this series of tests when plotted graphically and reduced to equations were as follows:

For inclination 30° $Pn=0.0015\ V^2$
For inclination 45° $Pn=0.0028\ V^2$
For inclination 60° $Pn=0.00335\ V^2$

where *Pn* is pressure normal to roof surface on windward side in pounds per square foot and *V* is velocity of wind in miles per hour.

It may be noted that for 60°, *Pn* is slightly greater than the former experiments showed for vertical surfaces.

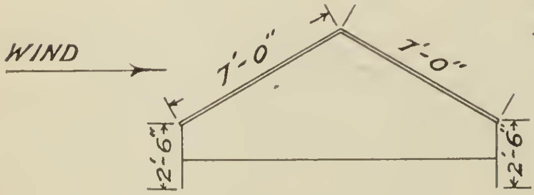


FIG. 1.

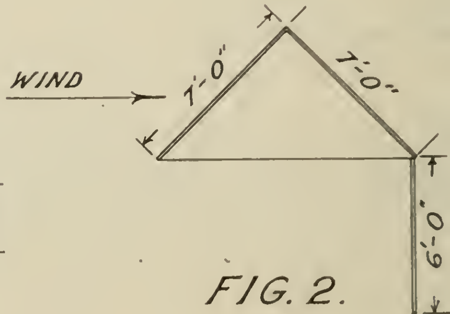


FIG. 2.

It was also found from this series that the pressures on the leeward side were much less than on the windward side, being negative for the 30° inclination. This led to another series of tests in which the depth of projection of the board below the leeward eaves was increased and the windward wall board omitted, see sketch (Fig. 2). These tests resulted in greatly increased negative pressures on the leeward side, the greatest negative pressures being for the smallest inclination of roof surface. This tendency will be referred to in describing the Nevada tests.

Mr. Stanton's idea in changing the wall boards from the way shown in Fig. 1 to that of Fig. 2 was "to obtain results which might be applicable to roofs supported on walls." After noting the results he remarks that the conditions of Fig. 2 roughly approximate "those of the roof of a building in which the windows and doors are open on the windward side and closed on the leeward side." It seems to the writer, in the light of his own experiments, that Mr. Stanton overlooked a very great difference between his model Fig. 2 and a building such as he compares it to, i. e., in that his model was 50 ft. above the ground, while the leeward wall of the building would extend clear to the ground, preventing the free passage of air underneath the roof.

THE NEVADA EXPERIMENTS.

As previously indicated, these experiments were under way before the writer knew of the English experiments by Mr. Stanton.

The model roof and house are shown by photograph Fig. 3 and sketch Fig. 4. The idea of the design is to approximate as nearly as possible an ordinary building roof, while permitting a considerable variation in the inclination, and yet keep within the narrow limits of allowable expense.

The main differences between the model and the reality, other

than size, lie in the fact that the model is open at the rear, i. e., on the leeward side, and has no projecting eaves. Also the shrinkage of lumber opened up cracks between the boards and there was a small opening under the windward and end walls. Notwithstanding these small openings at front and ends and the completely open rear,

Fig. 3.

several trials of the anemometer, held inside the house when the wind velocity was considerable, indicated very little motion of air and no definite direction to the same.

The roof surfaces, both windward and leeward, were covered with prepared waterproof roofing, and the gable ends closed with galvanized iron sheets, so hung as not to interfere with the motion of the roof up or down, except by friction from sliding over each other. At the lower ends of the leeward rafters, four in number, are small grooved wheels rolling on an iron track, such as are commonly used for sliding doors, to permit of changing the inclination of the roof. The range of inclination possible in experiment is from 15° to 70°, the end walls being extended back somewhat beyond that necessary for the 15° position. The main reason for leaving the leeward side open was the difficulty of satisfactorily closing it and still permitting the free motion of the above mentioned rollers on the track, on account of the interior bracing and timbers carrying said track. It is thought by the writer that the results of the tests do not differ materially from what they would be had this leeward side been closed.

Small canvas curtains, weighted with iron rods at the lower edge, cover the openings along the windward eaves and ridge. The writer now thinks that canvas could have been used with greater

convenience than the galvanized iron sheets for covering the gable-end openings.

The house was so mounted that it could be revolved through an arc of about 60° so as to face the wind, the center of rotation being at the center post of the windward face. Three other posts towards the rear of the house had small wheels at the bottoms which

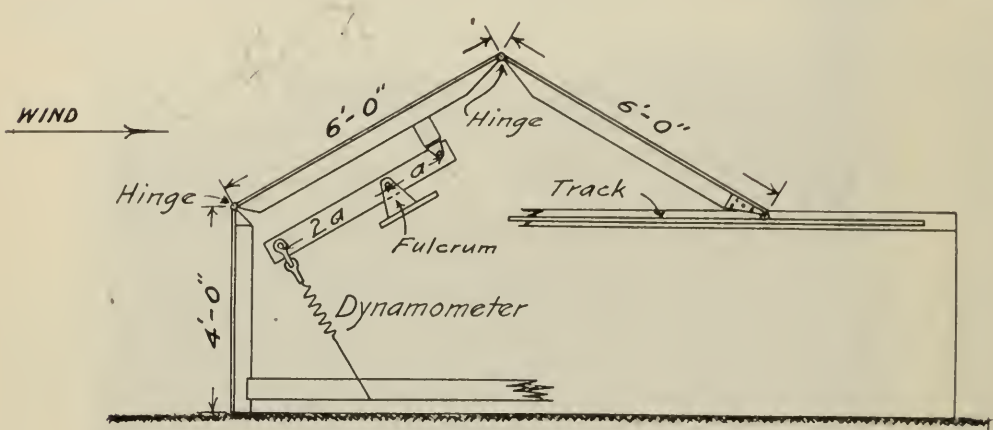


FIG. 4.

rolled on a wooden track, a part of which can be seen in the photograph, Fig. 3.

PRESSURE DETERMINATIONS.

The method of measuring the wind pressure against the windward slope is by means of a lever and a spring dynamometer as indicated by sketch, Fig. 4. This dynamometer and also the anemometer used in measuring wind velocities are shown by photographs Fig. 5a and Fig. 5b. The spring dynamometer has been tested several times with the results all practically agreeing on 144 lb. per in. of compression of the spring, indicated directly by a pointer moving along the scale shown on one side of the slot, Fig. 5a. This scale is divided into tenths of an inch.

The roof is 10 ft. long, thus giving 60 sq. ft. area on each slope. Assuming the pressure normal to the roof to be uniformly distributed over this 60 sq. ft., its value per square foot is found by the formula,—

$$Pn = (s\text{-}d)\frac{144 \text{x} 2 \text{x} 4}{60 \text{x} 3} = 6.4\ (s - d) \text{ where}$$

Pn is as used throughout this paper.

s is reading of dynamometer pointer in inches at the time of test.

d is reading of same pointer for dead load, i. e., no wind blowing.

FIRST SERIES OF TESTS.

Mr. J. E. Sears and Mr. J. A. Miller, graduates in civil engineering, class of 1910, started these tests for their graduating thesis.

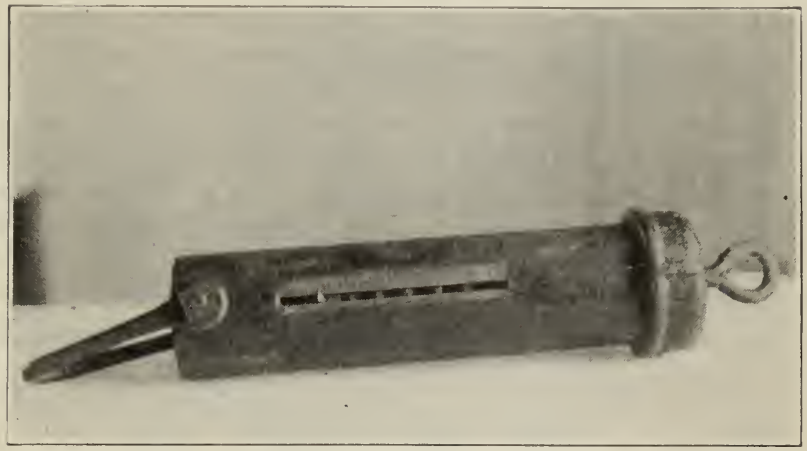


Fig. 5a.

Mr. Sears, under the writer's direction, made the detail plans of the wind house and he and Mr. Miller built the house.

Their tests, which were not very great in number, owing to the limited time remaining between the construction of the house and commencement day, are shown on the same diagram with all the others and will be discussed with them.

Fig. 5b.

ENVIRONMENT.

The prevailing wind, and probably 80% of all the wind blowing at Reno, is westerly, the air *flowing down* from the Sierra Nevada mountains. The exposure in the immediate vicinity of the wind house and for several hundred feet to windward is shown by Fig. 6. The contours indicate the altitude above sea level. To the westerly, across Virginia street, are scattering houses, the location being in the outskirts of the city. Westward from the city the ground gradually rises, up the Truckee River Valley, until, at the base of the main Sierra range ten miles west, the floor of the valley is about altitude 5000. The river valley there swings to the south and the Sierras rise abruptly to an altitude of 8000 to 9000 ft. Seven miles northwest of the University is the summit of Peavine mountain, altitude 8270 ft. About eight miles to the southwest is the summit of the north end of a spur of the Sierras, altitude nearly 9000 ft.

VELOCITY MEASUREMENTS.

The method used for measuring the wind velocity is shown in the photograph Fig. 3, the man holding the anemometer standing about 20 ft. to windward of the center of the wind house, and the altitude at which the anemometer is held differing but little from that of the center of the roof surface of the wind house. The anemometer has a stop-catch lever, by means of which the revolving pointers on the dial may be thrown out or in, but the vanes remain in motion without reference to whether the pointers are moving or not.

The method of taking observations was as follows: One person held the anemometer as shown; the other remained inside the house watching the dynamometer and operating a stop watch; when the inside man thought from the actions of the dynamometer it was a good time for a test, he shouted a signal to the outside man at the same time starting his stop watch; he kept his eyes on the dynamometer pointer and when it changed its position materially he shouted stop signal to the outside man, at the same time stopping his watch; he then recorded in a note book the estimated reading of the dynamometer, the time of test, and the number of feet movement of wind indicated by the anemometer for the time of the test, the latter being called to him by the outside man.

During most of the tests made by Sears and Miller, three men were used, one man operating the stop watch on the outside and transferring the signals to the inside man by striking the house with a stick. By this method the man with the anemometer was the one to give the original stop and start signals, but it was found better to let the inside man determine the time of test by the action of the dynamometer pointer.

When the wind velocity was high the noise from the galvanized-iron sheets and the canvas curtains made it much more difficult for the inside man to hear signals shouted by the anemometer man than vice versa, this being the reason for the third man under the first method.

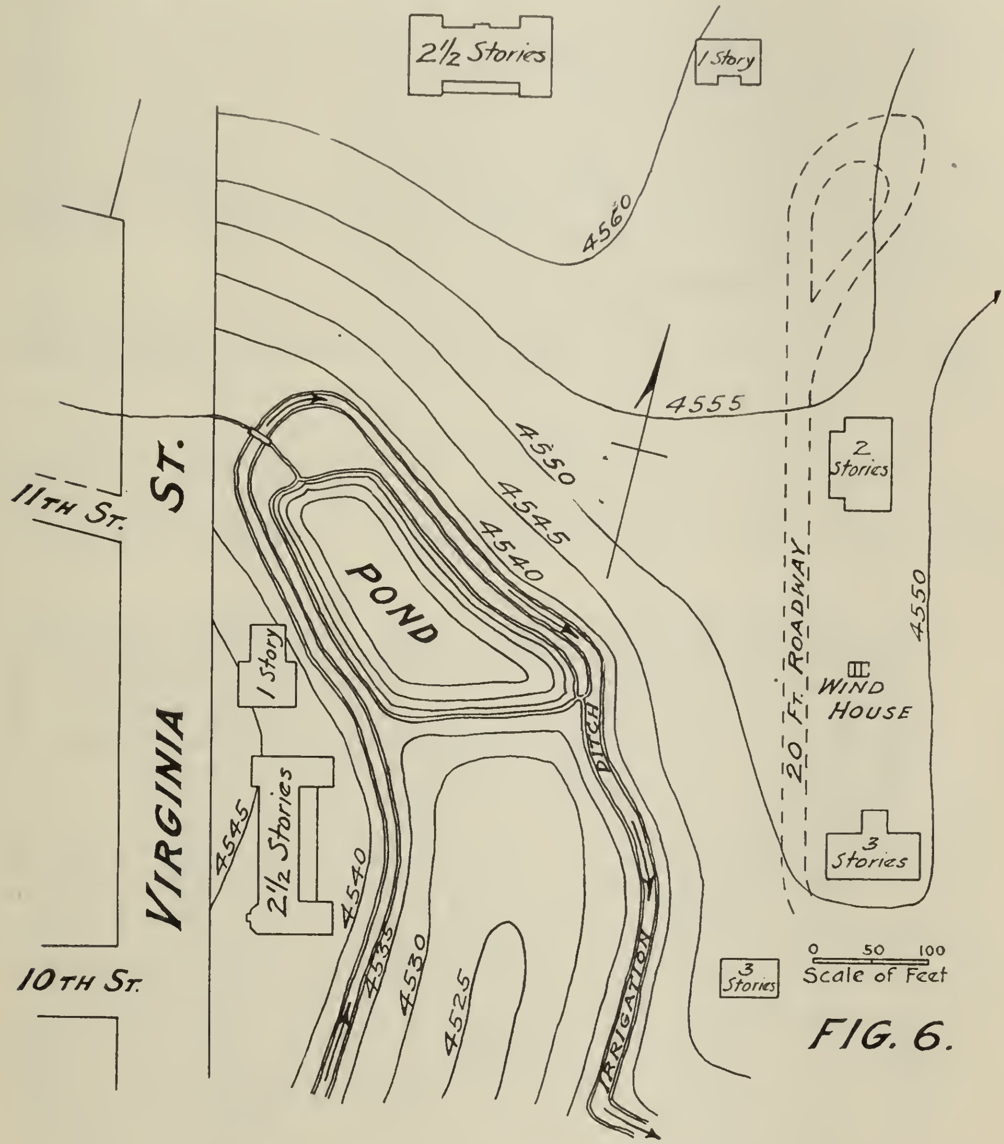


FIG. 6.

All the high velocities come in gusts lasting from a fraction of a second to ten seconds, but very few recorded tests were for less than two or three seconds. However, with the stop watch some few good tests were obtained for between one and two seconds.

This may appear to be a crude method for making such tests, but the writer believes that the results are as consistent as can be expected considering the great variability and sudden changes in the wind velocity.

In the fall of 1910 Mr. S. P. Ferguson, formerly of the Blue

Hill Observatory, Massachusetts, now in charge of meteorological work at the University of Nevada, suggested to the writer the advisability of testing the anemometer, since in his experience he had found considerable inaccuracies in many anemometers. The writer tested the anemometer in a large room with windows and doors closed, by revolving it about a vertical axis in a circle whose circumference was 50 ft. The distance indicated by the anemometer being compared with the actual distance traveled gives the correction to be applied, see Fig. 7. The anemometer was found to indicate too low velocities below 12.8 ft. per second, and too high velocities above that speed. The diagram, Fig. 7, also graphically reduces the erroneous velocities in feet per second (obtained by indicated anemometer distances divided by stop watch time), to corrected velocities in miles per hour.

The tests made by Sears and Miller were not corrected in this manner, but all tests made in the fall of 1910 and spring of 1911 were so corrected.

RESULTS OF TESTS.

The tests by Sears and Miller were individually reduced to give values V and Pn by the formulæ $V = \frac{15}{22} v$ and $Pn = 6.4\ (s - d)$

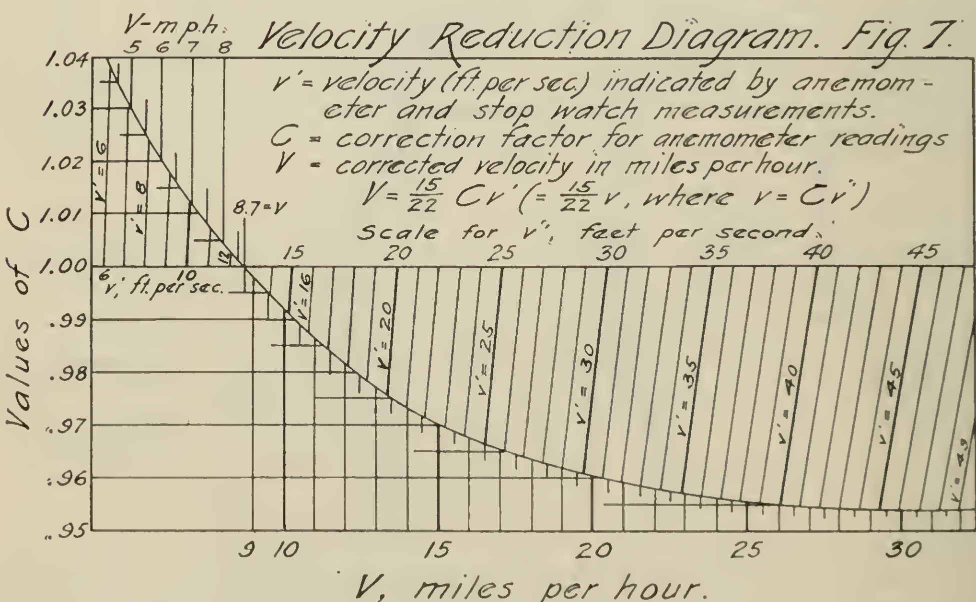


Fig. 7.

as previously explained, except that v was the anemometer record in feet divided by time in seconds and assumed as correct velocity in feet per second for the wind. These tests were not plotted individually but combined in groups by averaging all coming within a range of one mile per hour, i. e.

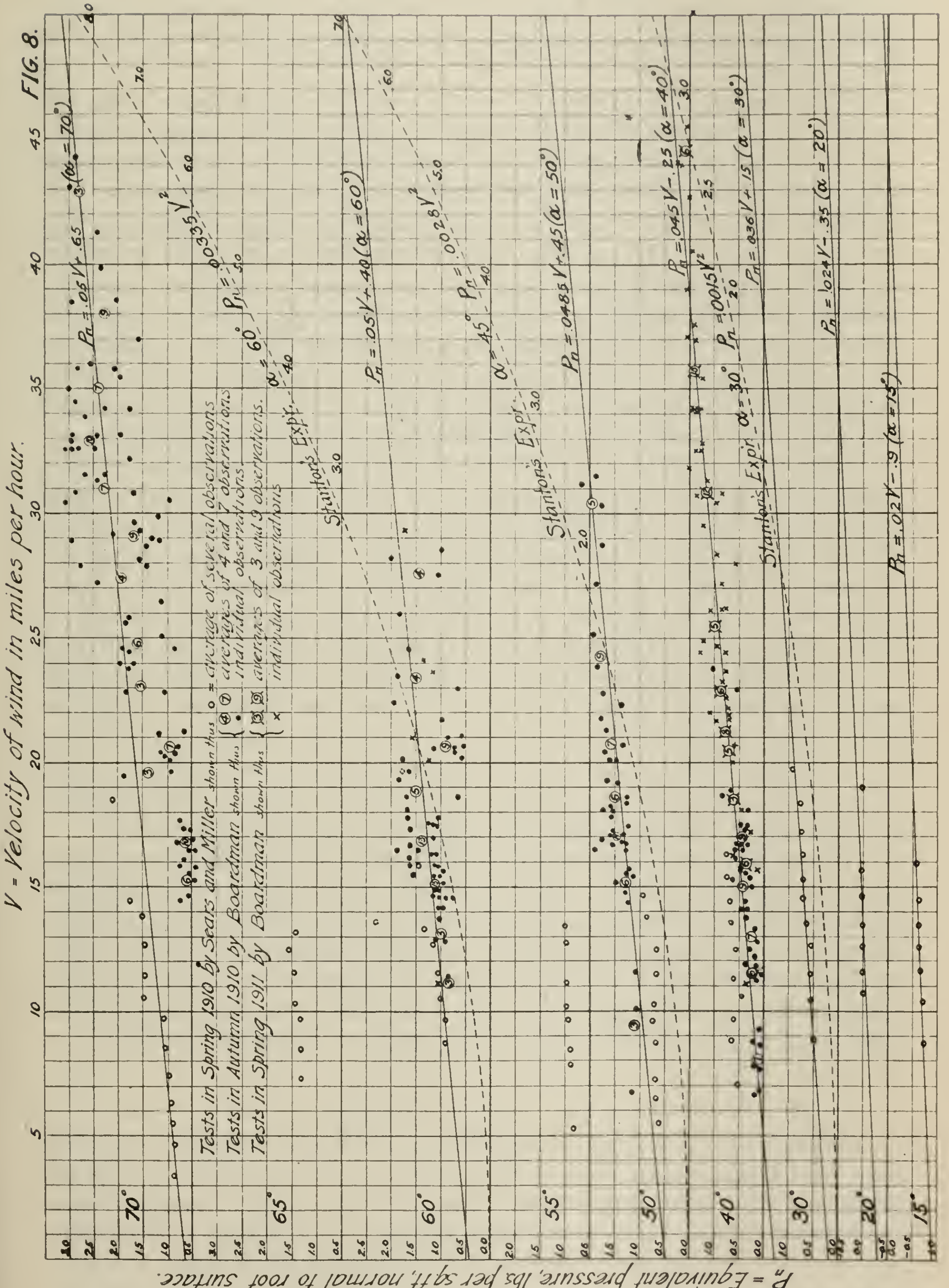

V = Velocity of wind in miles per hour.
P_n = Equivalent pressure, lbs. per sq. ft. normal to roof surface.
Tests in Spring 1910 by Sears and Miller shown thus o = average of several observations
Tests in Autumn 1910 by Boardman shown thus ④ ⑦ averages of 4 and 7 observations; • individual observations
Tests in Spring 1911 by Boardman shown thus ③ ⑨ averages of 3 and 9 observations; × individual observations
$P_n = .05V + .65$ ($\alpha = 70°$)
$P_n = .05V + .40$ ($\alpha = 60°$)
$P_n = .0485V + .45$ ($\alpha = 50°$)
$P_n = .045V - .25$ ($\alpha = 40°$)
$P_n = .036V + .15$ ($\alpha = 30°$)
$P_n = .024V - .35$ ($\alpha = 20°$)
$P_n = .02V - .9$ ($\alpha = 15°$)
$P_n = .0035V^2$ $\alpha = 60°$
$P_n = .0028V^2$ $\alpha = 45°$
$P_n = .0015V^2$ $\alpha = 30°$
Stanton's Expt.
70° 65° 60° 55° 50° 40° 30° 20° 15°

FIG. 8.

All between $V=10$ and $V=11$, one average.

All between $V=11$ and $V=12$, another average, etc., the corresponding values of Pn being also averaged. These averages were plotted on a diagram with values of V as abscissae and values of Pn as ordinates.

The writer, in making use of these tests, copied them from the diagram of Sears and Miller onto the diagram herewith shown. Fig. 8, which also includes all of the later tests. The later tests were reduced in the same way except that the velocities were corrected by use of the diagram, Fig. 7, as previously explained. As indicated, diagram Fig 8 shows individual tests and also averages in groups. The grouping for an average of these later tests usually included all tests within a range of two miles per hour velocity, as from $V=18$ to $V=19.9$ inclusive, the number of tests included in the average being indicated by the figure inclosed in the open circle. For the higher velocities the grouping into averages usually included a wider range of individual tests as they were more scattering.

The tests of Sears and Miller indicated that the plotted points, especially for the flatter inclinations of roof, grouped closely along straight lines with a slightly increasing steepness to those straight lines as the angle of inclination increased. But for the steeper inclinations of roof, it was more difficult to locate satisfactory average lines on the diagram. For this reason the writer, in the fall of 1910, made most of his tests at roof inclinations of 40°, 50°, 60° and 70°, obtaining a number of very satisfactory tests at 70° and wind velocities above 30 miles per hour and several above 40 miles per hour.

In April, 1911, a very good series of tests were obtained at 40° inclination, extending up well above 40 miles per hour wind velocity, one individual test figuring out a little over 50 miles per hour.

It may be noted that Sears and Miller's tests, which covered only a few windy days, included very few velocities as high as 20 miles per hour, while the writer's later tests were nearly all on days of quite heavy wind and included very few velocities below 15 miles per hour. In this connection the writer wishes to call attention to the fact that the diagrams of Mr. Stanton's tests include very few velocities as high as 25 miles per hour and none as high as 30 miles per hour.

DISCUSSION OF RESULTS.

While, of course, very uncertain of what the results of these tests would be, the writer had the model roof and building designed strong enough to stand pressures many times as great as any measured in the tests. This made the building as a whole considerably heavier than it need have been, and likewise resulted in the dynamometer spring proving less sensitive to changing velocities than was intended. However, since the position of the pointer, when quiet, could be estimated to within 0.02 in. of correct (equivalent to less

than 3 lb. or a variation of only 0.13 lb. in the value of Pn) this lack of sensitiveness may have been an advantage in preventing sudden and wide fluctuations in the position of the pointer.

The rather surprising results of Sears and Miller's tests, indicating as they did that pressures from high velocities would be much less than expected, made it desirable to extend the tests to as high velocities as possible, and the writer was gratified at being able to get numerous tests at velocities above 40 miles per hour.

The special reason for making so many tests at as steep a slope as 70° was that the pressures at that position should closely approximate those against a vertical surface.

The negative pressures obtained at low inclinations are not surprising in view of the results of Stanton's tests and others who have shown negative effects. In these Nevada tests the writer explains it as follows: The wind being deflected upward by the windward surface of the roof tends to draw with it and so rarefy the air over the leeward surface, thus permitting the air within the building to press upward with greater force than the air on top of the leeward surface presses down. This reasoning is supported by the behavior of the canvas curtain covering the crack at the ridge between the windward and leeward slopes. Always in a high wind when the roof is at a low inclination this curtain is bulged upward. On one such occasion the writer climbed onto the leeward slope and catching hold of the lower edge of the curtain, pulled it downward until the curtain lay flat on both slopes of the roof. Immediately on releasing it, the curtain bulged up again drawing the lower edge (which is weighted with a ½-in. round iron bar 10 ft. long) back at least 2 in. toward the ridge. Repeated trials always gave the same results.

Mr. Stanton's model roof was so mounted that he could rotate it clear around and thus measure the pressure on either leeward or windward slope, but only one at a time. As before noted, he obtained negative pressure on leeward slope at 30° inclination for his model, Fig. 1, and negative for all inclinations for Fig. 2 model, the negative pressure increasing (numerically) as the inclination decreased and as the velocity increased. He found no negative pressure on windward slope and it is not likely any would have been found in the Nevada tests had the method of measuring pressures been direct, but by the method used, if the net upward pressure on the leeward slope exceeded the downward pressure of the wind on the windward slope the result would be a lightening up of the pull on the dynamometer to less than that due to stationary air conditions or dead load, which was exactly what occurred at the inclination of 15°, and they practically balanced at 20°.

The tests by Sears and Miller seemed to indicate a straight-line formula for the relation between Pn and V for each inclination of the roof, and this type of formula seems completely justified by the

writer's later tests, especially at inclinations of 40° and 70°, at which positions the maximum velocities were tested. The wide divergence between these tests and those of Mr. Stanton is clearly shown by plotting on Fig. 8, the parabolas for the pressures found by Mr. Stanton, and noting how much lower his pressures were for velocities under 15 miles per hour and how much higher for velocities above 25 or 30 miles per hour.

To get the relation at any given velocity between *Pn* and the inclination of the roof surface, the points plotted on diagram, Fig. 9, were computed for velocities 10, 30, 50, and 100 miles per hour from the straight-line formulae shown on diagram, Fig. 8, for the different inclinations from 15° to 70°.

It must be confessed by the writer that in selecting the straight lines taken as averages on Fig. 8 diagram, he was somewhat influenced by the way the points obtained from them plotted on diagram Fig. 9, for the reason that it seemed to him there should be some regular law of increase in presure with increase in steepness of inclination. The results on both diagrams appear to justify in a general way this small amount of juggling, but it was found impossible to make the tests at the 40° inclination give consistent points on diagram Fig. 9, all of them falling below the lines drawn in for the respective velocities.

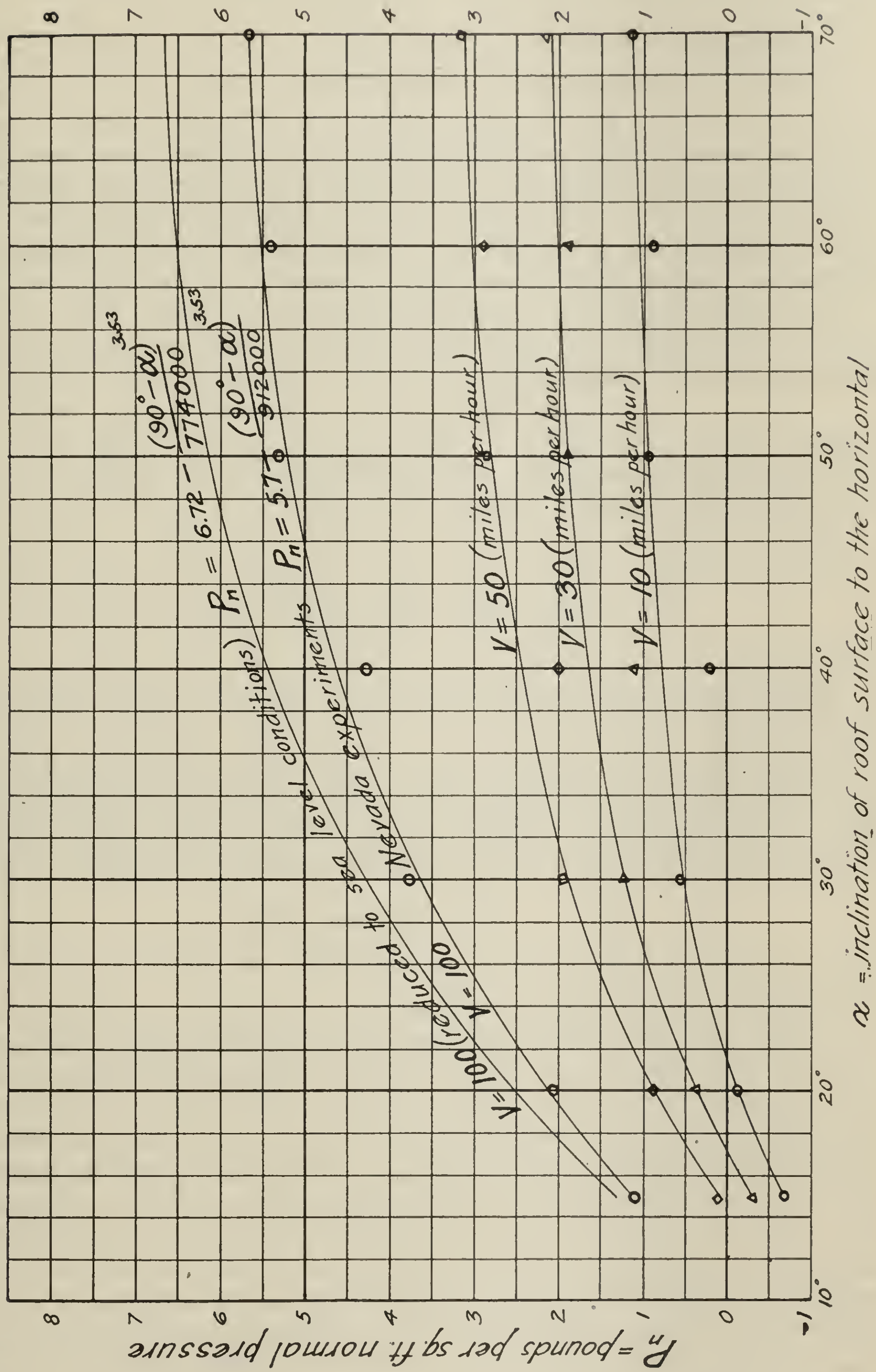
The writer is unable to offer a solution for this discrepancy, especially since the later tests at 40° inclination (the very last tests he made) seem to give the most definite location of any of the straight lines shown on diagram Fig. 8.

Since $V=100$ corresponds quite closely, in Stanton's formula, for pressure against a vertical surface in free exposure, to pressure commonly taken as the maximum in designing structures, the writer computed a formula that fits quite consistently to the points plotted on diagram Fig. 9 for $V=100$. In devising this formula the writer first assumed, from the appearance of the curves drawn in "by eye," that the equation should be of the parabolic type with vertex on the vertical through 90° inclination. The first assumption for *Pn* at the vertex was 5.8 lb. Using x and y as referring to an origin at this vertex gave $x=(90°-\alpha)$ and $y=(5.8-Pn)$. Then assuming the general type of parabolic formula with origin at the vertex we have $x^n=Ky$, where n is an unknown exponent and K an unknown coefficient. Transposing this into the logarithmic type of formula we have $n \log x = \log y + \log K$. Since K and n are constants, this is a typical straight-line formula as

$$Y = mX + b$$
$$\text{or } (\log y) = n\,(\log\ x) - (\log K).$$

Next, selecting two points besides the vertex through which it is desired to pass the curve, gives us two values of x and two of y, hence two values of $\log x$ and two of $\log y$. The constants n and

FIG. 9.



$P_n = 6.72 - \frac{(90^\circ - \alpha)^{3.53}}{774000}$
$P_n = 5.7 - \frac{(90^\circ - \alpha)^{3.53}}{912000}$
V = 100 (reduced to sea level conditions)
V = 100 Nevada experiments
V = 50 (miles per hour)
V = 30 (miles per hour)
V = 10 (miles per hour)
P_n = pounds per sq. ft. normal pressure
α = inclination of roof surface to the horizontal

(log K) can then be obtained either analytically or graphically. The two values of x and y chosen in this case were

x=40° and 70° or α = 50° and 20°

and y=0.6 and 3.65 or Pn=5.2 and 2.15.

This gave equation $\left[x^{3.23} = 246{,}000\ y\right]$. On plotting the points at every 10° value of x (or α) it was seen that this equation could be improved on, so another trial was made assuming vertex at Pn=5.7 and α = 90°, giving x = (90°— α) and y = (5.7—Pn). Then assuming the points, other than vertex, to pass the curve through as

x = 40° and 70° or α = 50° and 20°

and y = 0.5 and 3.6 or Pn = 5.2 and 2.1, by the same method the following equation was obtained,

$$\left[x^{3.53} = 912{,}000\ y\right] \text{ or } \left[(90° - \alpha)^{3.53} = 912{,}000\ (5.7 - Pn)\right].$$

Solving for Pn gives $Pn = 5.7 - y$

Or

$$\left[Pn = 5.7 - \frac{(90° - \alpha)^{3.53}}{912{,}000}\right].$$

This equation when plotted gave the curve as drawn in on diagram Fig. 9.

Since the atmospheric pressure at sea level is about 18% greater than at Reno, it seemed reasonable to assume that the wind pressures at sea level would also be 18% greater than at Reno, so the above equation was changed by increasing the values of Pn 18%, giving

$$\left[Pn = 6.72 - \frac{(90° - \alpha)^{3.53}}{774{,}000}\right]$$

and the curve as plotted on the diagram.

As to the great difference in results between these tests and those of Mr. Stanton, the writer would again call attention to the fact that Mr. Stanton's model roof was 50 ft. above the ground, while the writer's was connected to the ground by a 4 ft. wall. Where an obstruction like the model house is continuous from the ground up to the top, there must be a stoppage of the air on its windward side much more effective than where the obstruction is well above the ground, permitting free passage of air under as well as above and at the ends. This greater interruption to the movement of the air probably causes a deflection of the main air current upward and around the ends at a point farther from the building than if it were elevated above the ground, thus forming a cushion of stationary or eddying air next to the building and shielding it from the direct impact of the main air current.

Professor Francis E. Nipher of Washington University, Missouri, in reply to a letter from the writer, answered in February, 1911, with a sketch and statement to the effect that in a high wind the maximum pressure normal to the roof is at the windward eaves and that it decreases to zero at a point (on his sketch) about three-fourths of the way up to the ridge. Beyond that point on the windward slope and on the whole leeward slope he says it is negative. This may be a correct statement, and doubtless Professor Nipher has good grounds for making such a statement, as he has made extensive measurements of air currents, but as the writer's apparatus was not designed so as to reveal any such possible variation in unit pressure on different parts of the surface, he continued his deductions on the assumption of uniform distribution of pressure over the whole windward surface, which assumption seems to have been very generally accepted, although perhaps erroneously.

The writer thinks that his style of model for testing the wind pressures gives results more applicable to ordinary building roofs after the buildings are completed than does Mr. Stanton's type of model, but if at some stage of construction the building is completely roofed over before the walls are closed in, probably Mr. Stanton's results would be closer to correct for that case.

It would seem that there is still ample room for experiment along this line, both as to different arrangements of roof on walls or without walls, height above the ground, relation of length to height of building, and the writer has thought the type of roof covering, whether smooth or rough, as shingles or tiling, might have some effect on the results. Also tests along the line indicated by Professor Nipher's comments should be made. The writer hopes to be able to do further work along some of these lines in the future.

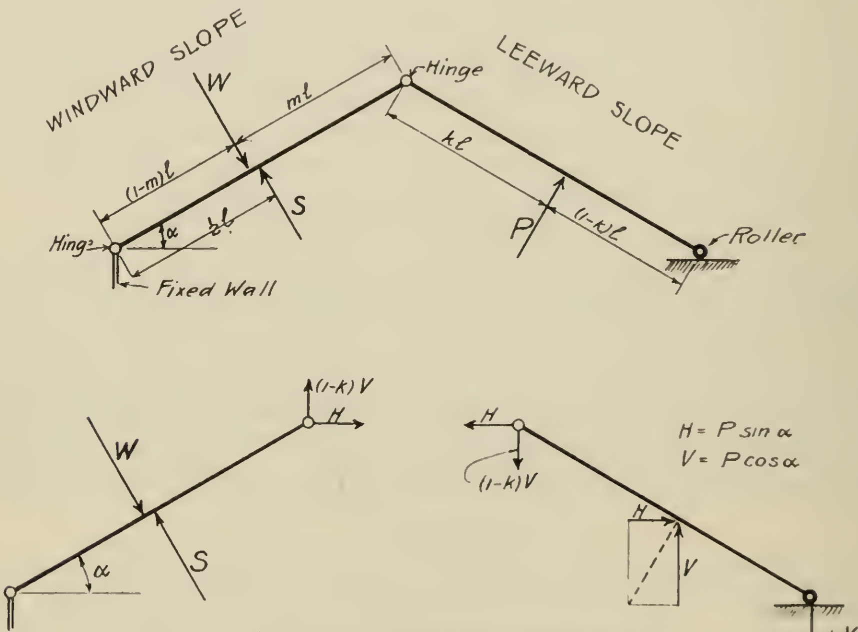
DISCUSSION.

O. H. Basquin, M. W. S. E.: I have three criticisms to make of this paper. They relate to the use of the anemometer, to the assumption that the pressure is uniformly distributed over the windward slope, and to the entire neglect of wind pressure on the leeward slope of the roof.

The anemometer is a proper instrument for measuring the speed of a steady wind. Its use involves the measurement of an interval of time. In a steady wind this interval may be made long enough to reach any desired accuracy of measurement, but in a high wind the interval must be made very short for the reason that the speed of the wind is constantly changing, and the short interval cannot be accurately estimated without special apparatus. Stanton, in his experiments, used a sort of Pitot tube, similar to the device which has been so much used in measuring the flow of water. This instrument indicates the speed, which is obtained at a single reading. The device seems superior to the anemometer in that it does not involve the measurement of an interval.

My second point is that the resultant pressure of the wind upon the windward slope is probably not at the center of that roof. The assumption of uniform pressure has been made by the author in deriving his working formula for the reduction of all of his observations. If one is designing a roof truss, he is at liberty to assume a uniform distribution of pressure; such assumptions are necessary for the sake of simplicity; but if one is attempting to measure the actual force on a roof by experiment, he is hardly at liberty to assume any particular distribution of pressure (if this assumption affects his result) unless he shows good reason for thinking that this distribution is the actual one.

The third point was mentioned by Professor Smith, namely, that the author has neglected altogether the normal pressure upon the leeward surface of the roof. He ought to show either that there



$\frac{1}{2}S - (1-m)W - H\sin\alpha + (1-k)V\cos\alpha = 0.$

$S = 2(1-m)W + 2P(\sin^2\alpha - (1-k)\cos^2\alpha).$

FIG. 10

is no pressure upon that surface, or that it would not interfere with the results if there is such pressure.

A diagram of the roof system used by the author is shown in Fig. 10. The windward leaf is hinged to the fixed wall at its lower edge and to the leeward leaf at the ridge, while the lower edge of the leeward leaf rests on rollers running upon horizontal tracks. For a roof 1 ft. in length we may assume an inward normal resultant force W on the windward slope at a distance ml from the ridge, and an outward normal force P on the leeward slope at a distance kl from the ridge. We have a vertical reaction at the leeward eaves, an unknown reaction at the windward eaves, and a force

S introduced at the middle of the windward slope—the force of the spring—to preserve equilibrium. In the lower part of Fig. 10 the two leaves are shown separated in order that the equal and opposite forces at the ridge may be clearly indicated. If we consider the windward leaf and find the sum of the moments about the lower hinge of all forces acting upon this leaf, and set this sum equal to zero, we have the first equation of Fig. 10, while the second equation is derived immediately from the first and gives the value of S —the reading of the spring or dynamometer used in these tests.

In this equation for S we may notice, first, that W enters with the coefficient $_2(l\text{-}m)$ which is unity only when m is ½ and, second, that P enters with a coefficient that is not zero, so that S will be equal to W only when $m=\frac{1}{2}$ and $P=O$.

Let us now take up briefly the tests of other experimenters, to see if they throw any light upon these two points at issue, namely, the location of the center of pressure on the windward slope, and the amount of the pressure on the leeward slope.

In 1894 Irminger read a paper describing experiments upon some small models held in a steady stream of air. His results are given in *Engineering News,* February 14, 1895, and are extensively referred to by Professor Smith, in his paper on "Wind Loads on Mill Building Bents," published in the *Journal of the Western Society of Engineers* February, 1911. Irminger's pressures relate to the outside of the roof only. On the windward slope he found an inward pressure at the eaves and a small outward pressure at the ridge, so that the center of pressure would be below the middle of that slope. On the leeward slope he found an outward pressure or suction equal to that in the rear of the building, so that if the rear had been open, as in the experiments of the author, the resultant force on the leeward slope would doubtless have been zero —namely, for the conditions used by Irminger who employed a slope of 45° only.

The author refers to certain experiments made by Stanton, but he refers only to a second set of his experiments. Stanton's first set is described in the *Proceedings of the Institution of Civil Engineers, Vol. 156, 1904.** Following the method of Irminger, Stanton placed small models in a steady stream of air and measured the normal pressure at various points of their exterior surfaces, and at different speeds of the air current. He used roof slopes of 30°, 45°, and 60°. Let us consider his results on the model having a roof slope of 60° in a current of air having a speed of ten miles an hour. Stanton's results are shown at A in Fig. 11. The arrows show the direction of the outside pressure, and they are drawn in the approximate positions for which the pressure was determined. The negative pressure or suction on the vertical face on the leeward side of the

*See also—*Engineering,* Vol. 60, p. 787, Dec. 27, 1895. Marburg, *Framed Structures and Girders,* Vol. 1, p. 134, 1911.

house is nearly uniform. If this leeward side had been open, as in the case of the author's experiments, this negative pressure would have extended to the interior of the house, and the resultant or combined pressure on each surface would have been the sum of the outside pressure and inside negative pressure. This combination is shown at *B*, Fig. 11. The pressure on the windward slope is materially larger than before, and its center is somewhat below the center of the slope, but the resultant pressure on the leeward slope is almost zero. At higher speeds this pressure is inward and is not so small in comparison with the other pressures, although it is not at all large. At a slope of 30° this resultant pressure is outward and larger in proportion to the other pressures than at a slope of 60°. The combined pressure per square foot on the windward side of a 60° slope, as found in the above manner, has a value of about $0.0026V^2$, although no great accuracy can be claimed for this constant on account of the small dimensions of the model and the small speed of the air currents used.

Stanton found the inward pressure on the outside of the wind-

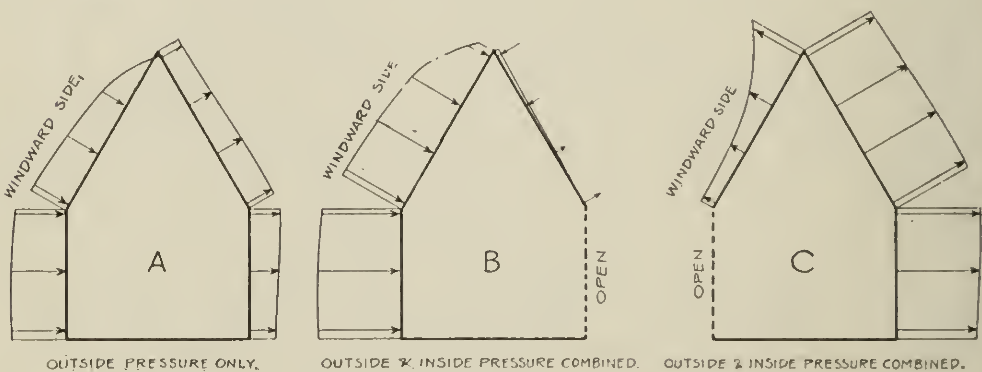


FIG. 11

ward vertical face of his model to be nearly uniform; if that face had been open and the remainder of his model closed, we may assume that this pressure would have extended to the interior of the model, giving combined pressures for the remainder of the model somewhat like those shown at *C* in Fig. 11. In this case we have an outward force acting upon the windward slope of a magnitude about half that shown at *B*, and whose center of pressure is considerably above the center of that roof. On the leeward slope we have a large outward pressure nearly uniform over the surface of that slope; its value is about $0.0038V^2$ per sq. ft.

In Stanton's later experiments on a large model, he hinges his windward slope at one end instead of at the top or bottom in order, as he explains, to obviate the uncertainty as to the location of this center of pressure. In a wind at 20 miles per hour he finds that the pressure on the leeward slope at 60° is inward and equal to about 11% of the pressure on the windward slope; at a slope of 45° the

leeward pressure is negligible; and at a slope of 30° the leeward pressure is outward and equal to about 26% of the pressure on the windward slope.

In order to substantiate these conclusions, I tried an experiment myself, using a model that was made as nearly like the one used by Professor Boardman as could be conveniently made. The model was made of sheet tin, the roof being 10 in. along the slope instead of 6 ft., and the whole model was made smaller than the author's shed in the same ratio, namely 1:7.2. The slope of the roof was 30°. The model was placed about 8 ft. in front of a small blower giving a steady current of about 10 miles an hour, but unfortunately

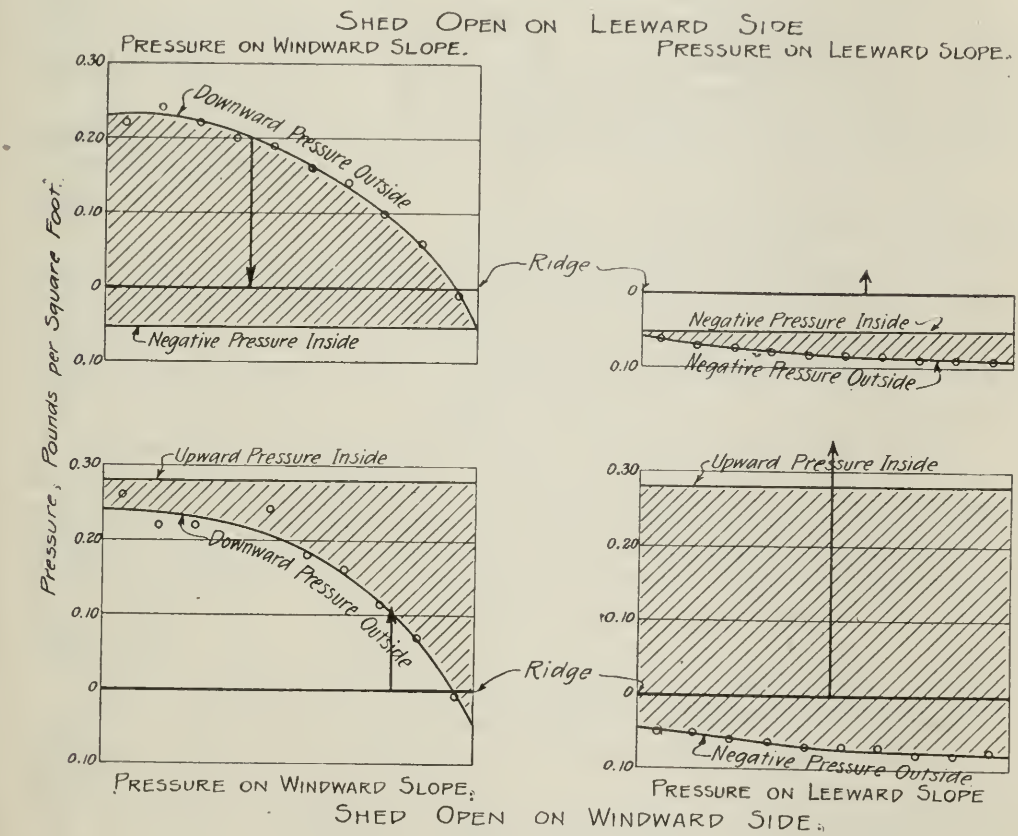


FIG. 12.

for the accuracy of this test the speed was not very uniform in different parts of the stream. A series of ten holes 0.04 in. in diameter had been made along the center line of each slope of the roof, and the exterior pressure was determined at each hole by means of a manometer standing in still air.

The results of the test when the leeward side of the building was open are shown in the upper part of Fig. 12. On the windward side we find an inward pressure both on the outside and on the inside, the total pressure being the sum of the two and forming the cross-hatched area shown; its center of pressure is dis-

placed about one-tenth the length of the slope from its center. On the leeward slope we find an outward pressure on the outside, and an inward pressure on the inside; the resultant is their difference and is shown as the rather small cross-hatched area. This leeward force is about one-tenth that on the windward slope.

On raising the model about 4 in. so that the vertical face of the model would receive the full force of the wind, the pressures obtained as above were practically the same except that the pressure became negative on the outside of the windward slope at its lower edge—a result obtained by Stanton in his work with the model having a 30° slope.

In the lower part of Fig. 12 the results obtained when the model was turned around so that the windward side was open, are shown. On the windward slope there is now, on the inside, a larger outward pressure than the inward pressure on the outside, the resultant being the cross-hatched area shown, whose center is considerably displaced toward the ridge. On the leeward side there is an outward pressure on both sides of that slope, the resultant being their sum, the large shaded area shown.

In conclusion, it seems clear that the author's results are considerably in error on account of the displacement of the center of pressure on the windward slope; that the pressure on the leeward slope is not very large; and that the maximum force exerted upon a roof is an *upward* force on the *leeward* slope.

Albert Smith, M. W. S. E.: This paper on wind pressure is timely and on an exceedingly interesting subject,—one worthy of careful consideration. The question is not settled and ought to be.

The present assumptions for normal wind pressure are exceedingly unsatisfactory. These assumptions, based on Stanton's and Duchemin's experiments, assume that the *total* wind effect on a plate in a current of air will be the same as that on the same plate when it forms a part of the wall or roof of a building.

Irminger's and Stanton's experiments have settled beyond question the fact that, of the total force on a plate exposed to a current of air, a considerable portion is on the leeward side. Indeed, for small inclinations the windward effect is negative and it is the suction effect on the leeward side which seems to give a normal pressure. If the action of this suction on the inside surface of the wall or roof be prevented, as is almost always the case in buildings, there will result forces on the walls and roofs which not only do not approximate, but which may even be of opposite sign from those which we have been deriving so laboriously from exact formulæ.

It is probable that few buildings have failed on this account, although I recall failures of very large drill halls and convention halls, which might be traced to forces unexpected by their designers. Even if no failures had ever taken place, all engineers would prefer to do their guessing with all the ascertainable facts in hand.

In examining Fig. 4 and the description thereof, I am inclined to think that results with this model should be considered as applying only to buildings with one side completely open. The suction which the author notes as existing on the leeward roof slope also undoubtedly exists on the inside of the building, and constitutes a downward pulling force on both windward and leeward roof. If the leeward side were closed, this effect would not be present on the inside and the results would be very different.

In regard to the arrangement of dynamometer and roof support, which I understand to have been 4 ft. from the windward eave, it seems to me that the dynamometer supports not only the windward but the leeward roof also. If the leeward roof receives any suction from the wind, there will then be a force applied at the peak hinge, which has been disregarded here.

I would suggest, in continuation of these experiments, that the normal pressure on the leeward side be tested, and if of any considerable size that it be applied as a correction to the pressure formula.

There is a point which is not taken account of in these experiments, and which might prove to be of some importance. Stanton's tests on small models in an artificial current of air showed a varying pressure over the surface of the windward roof. It might be possible, then, that the total pressure is not 8/3 of the dynamometer pull, but something much larger.

Francis E. Nipher (Washington Univ., St. Louis): The assumption made in the paper, that the normal pressure on a roof, or on an inclined surface exposed to wind, is uniformly distributed is fundamentally wrong. The air which drifts up the roof and over the ridge deflects the air currents which are on a level with the upper part of the roof, and their pressure effects are thereby diminished.

If the author will remove the hinges at the windward eave of his model, Fig. 4, and fix the ones at the ridge, so that he can measure the moments with reference to the ridge, he will obtain very different results.

A board mounted on pivots at its upper and lower edges, the pivots being at the middle of the board, will set in stable equilibrium at right angles to the lines of flow.

A building tends to turn on its foundations until a side of it faces the wind. This can easily be shown by means of a cubical model suspended on cords attached to the middle points of its upper and lower faces. The model may be a frame having all sides closed with stiff paper.

The pressures on and within buildings are very much modified by their various forms. The only way in which reliable values can be obtained is by actually measuring pressures at various points on the buildings themselves. Experiments on models have comparatively little value.

April, 1912

The only method which I have been able to find for doing this is discussed in the following papers:

"The Elimination of Velocity Effects in Measuring Pressures in a Fluid Stream." Francis E. Nipher. Proc. Amer. Philosophical Society, Vol. XLV, 1906.

"On Pressure Measurements in a Fluid Stream." Francis E. Nipher. Trans. The Academy of Science of St. Louis, Vol. XVI, No. 3, 1906.

The United States Weather Bureau should be induced to take up this work at its central experiment station, for it could obtain results which would have great value.

CLOSURE.

The Author: In replying to Professor Basquin's criticisms, I shall first discuss the use of the anemometer and stop watch for measuring wind velocities. That method was used as it was the one most readily available and did not involve much expense. Also, I had had no experience in the use of Pitot tubes or velocity tubes of any kind for such purposes.

Stanton's use of velocity tubes and gauges is probably preferable to the anemometer method, but, on examination of his paper, it is evident that that method did not overcome all the difficulties, which he enumerates as follows: "(1) The possibility of a 'damping' of the pressure and velocity indications owing to the length and small diameter of the connecting pipes. (2) The existence of a time-lag in the indications of the gauges and the possibility that the amount of the time-lag might be different in the two sets of tubes. (3) The possibility of a sufficiently rapid adjustment of the gauges not being made under the rapid fluctuations of wind velocity which are known to obtain."

To overcome these difficulties it was considered advisable to limit the observations to intervals of practically steady wind lasting for at least three seconds. These did not always coincide for the velocity and pressure apparatus so the two observers, one at velocity gauge and the other at pressure gauge, had to signal each other so their test records would be taken only at times of simultaneous periods of practically uniform velocity and pressure lasting for at least three seconds.

A third observer, at the top of the tower, was required to adjust the pressure board or roof to the direction of the wind. I think we encountered no worse difficulties in our Nevada methods, and that the grouping of our experimental results about the average lines drawn in on Fig. 8 indicates as consistent results as do Mr. Stanton's tests, and are as good as can be expected for that type of experiment, dealing with anything as fluctuating as wind velocity and pressure. I am confident that the anemometer as corrected in accordance with my whirling table rating, indicated quite accurately the space factor of the wind velocity and the stop watch measured time to fifths of a second.

Regarding the outward normal pressure on the leeward surface of the roof, I did neglect this in my computations, although reference to my paper, "Discussion of Results," fourth paragraph, will show that I did not entirely overlook it. My reasons for not taking account of it in computations are that my apparatus afforded no method of measuring it experimentally and I was reasonably sure that it was not large in amount. Theoretically, such a decision may seem unjustifiable, but I was after practical results and my apparatus was not so designed as to warrant hair splitting refinements in computations.

Professor Basquin's reference to Stanton's earlier experiments (Fig. 11, B) and his deductions from his own recent experiments with a small model seem to bear out the conclusion that, in the case of my wind house, open to leeward, the pressure on the leeward slope was small in proportion to that on the windward slope.

Referring to Professor Basquin's analysis of my roof (Fig. 10), some errors should be corrected.

First, considering the sketch of detached leeward slope of roof, taking moments about the hinge at ridge.

$Pkl =$ vertical reaction at roller times $l \cos \alpha$; hence, roller reaction $= \dfrac{Pk}{\cos \alpha} = \dfrac{kV}{\cos^2 \alpha}$, since $P = \dfrac{V}{\cos \alpha}$.

Since V equals the sum of vertical reactions at roller and at ridge,

then $V - \dfrac{kV}{\cos^2 \alpha} = V \left(1 - \dfrac{k}{\cos^2 \alpha}\right)$, the vertical component of the ridge reaction.

Second, considering the windward slope of the roof, I will first correct a dimension. In my roof, S was applied 4 ft. from the eaves hinge, or 2/3 l from that hinge, since l equals 6 ft. I should have shown that dimension 4 ft. in Fig. 4.

Taking moments about the eaves hinge,—

$$2/3\, l\, S = W(1-m)\, l + H\, l \sin \alpha - V \left(1 - \frac{k}{\cos^2 \alpha}\right) l \cos \alpha$$

but $H = P \sin \alpha$ and $V = P \cos \alpha$,

$$\text{hence } S = 3/2 \left[W(1-m) + P \sin^2 \alpha - P \cos^2 \alpha \left(1 - \frac{k}{\cos^2 \alpha}\right)\right]$$

$$\text{or } S = 3/2\, W\, (1-m) + 3/2\, P\, (\sin^2 \alpha - \cos^2 \alpha + k),$$

which is somewhat different from the value Professor Basquin obtained for S.

Let $(\sin^2 \alpha - \cos^2 \alpha + k) = M$. Then we have $S = 3/2\, W(1-m) + 3/2\, PM$.

I have computed the following values for M, assuming $k = 0.5$.

α	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°
M	−.44	−.366	−.266	−.143	0	+.158	+.326	+.50	+.674	+.842	+1.0	+1.143	+1.266

From this it is seen that if an upward and outward force P was acting on the windward slope of my roof, its effect was to decrease the force S when α was less than 30°, and to increase S when α was greater than 30°, providing this force P acted symmetrically on the windward slope. To state it the other way around, since S was the measured force in the experiments, by neglecting P I probably obtain too low values for W when α is less than 30°, and too high values for W when α is greater than 30°. If k were not equal to 0.5 (Fig. 10), the angle of zero effect would not be 30°. If P is not greater than $\frac{W}{10}$, it is evident that the effect of P is not great for the ordinary slopes of roofs. If the roof were fixed at leeward eaves, the angle of zero effect would be 45°, but the formula for S would differ from that given above.

The criticism made by all discussing the paper, that the assumption of uniform distribution of pressure over the windward surface is wrong, was expected and is doubtless warranted. At the time of writing the paper I had not available all of the literature referred to, though I did have one reference—the *Engineering News* account of Irminger's experiments—which I overlooked, not knowing it was in that publication. Even at the present writing I have not seen any account of other tests which are similar to mine in the respect of resembling an actual building standing on the ground, so it is not yet proven to my satisfaction what the distribution of said windward pressure was.

I inferred from Stanton's paper that he concluded the center of pressure on the windward side was not eccentric to any great extent, though he had no means of determining it definitely. Irminger's tests indicate eccentricity, but the conditions of his tests were very different from mine. However, I am willing to grant the *probability* of the center of pressure being displaced towards the windward eaves to a considerable extent and so have determined the wind stresses in a typical roof, 60 ft. span by 15 ft. rise, on the basis of three cases which are as follows:

(1) Pressure as determined by my experiments (reduced to sea level basis) on the assumption of uniform distribution over the windward slope and zero on leeward slope.

(2) Pressure as determined by my experiments (reduced to sea level basis) on the assumption that the unit pressure varies uniformly from a maximum at the windward eaves to zero at the ridge, *i. e.*, center of pressure at 1/3 distance from eaves to ridge.

(3) Pressure uniformly distributed and determined by Hutton's formula, which is given on the second page of my paper.

The value of Pn from Hutton's formula for this roof, assuming 30 lb. sq. ft. pressure against a vertical surface, is about 18 lb., and

this was used for case (3). For case (1) I used 3.75 lb., obtained from my curve Fig. 9 for $V = 100$ (reduced to sea level conditions) for 26° 34′, which is the inclination of this roof. For case (2) the pressure was found as follows: Assuming *pm* equals maximum pressure per square foot at windward eaves and W_2 equals total pressure on windward slope per foot length of building, then equating moments about hinge at eaves, $W_2 . \frac{l}{3} = Pn\ l . \frac{l}{2}$, or $W_2 = 3/2\ Pn\ l$; and since *pm* equals twice average pressure on slope, $pm = 2 \left(\frac{W_2}{l}\right) = 3\ Pn$, or 11.25 lb. per sq. ft. for the roof under consideration.

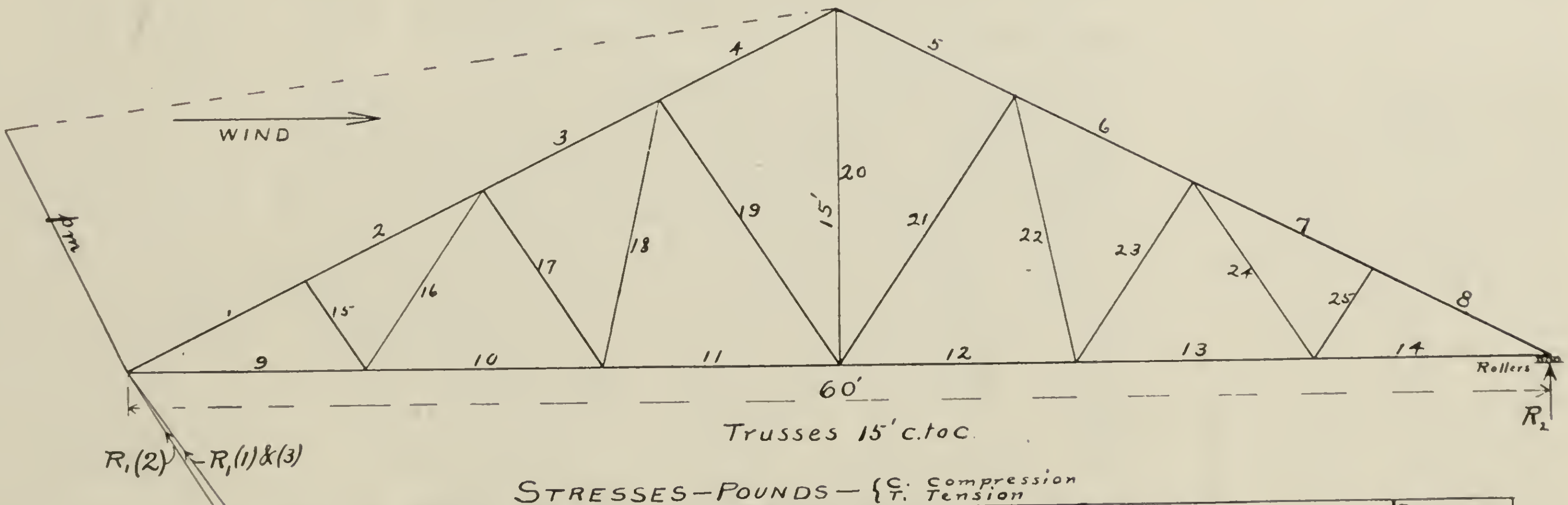
On this basis I found graphically the stresses in the different members and the reactions as shown on sketch, Fig. 13. In comparing these stresses it is seen that the right reaction and the leeward stresses are the same in cases (1) and (2). This must be so since both cases (1) and (2) are based on the Nevada experiments, wherein the rotative effect about the windward eaves was measured and R_2 is directly proportional to this amount. In the windward part of the truss the top chord stresses, case (2), are from 10% to 50% greater than in case (1). In the bottom chord this excess is from 10% to 45%, while in the web members it is from 25% to 122%. As seems natural, the greatest differences between the stresses of case (1) and case (2) are near the windward eaves where the pressure is assumed a maximum for case (2). Please note that case (3), based on Hutton's formula, gives stresses nearly five times those of case (1) and from two to five times those of case (2).

I agree with Professor Nipher that experiments on models, especially small ones in artificial air currents, are not of great value and that much more valuable results should be obtained from actual, full size buildings. It is interesting to note that Professor Nipher has shown that velocity tubes, to indicate zero effect in a current of air, should be turned at an angle of 60° toward the moving air instead of at an angle of 90° with its direction of motion.

If I understand Stanton's description of his velocity tubes correctly, he turned one at 90° to the direction of motion, though his illustration was not clear to me when taken with his word description of said velocity tubes.

I think that in the past, in the matter of wind pressures against roofs and earth pressures against retaining walls, and possibly some other lines of investigation, although too much reliance has been placed on mathematical deductions based, to some extent, on very incomplete and small scale experiments, but based more largely on *assumptions* which are as fundamentally wrong as, in all probability, is the one I made of uniform distribution of pressure.

It may be noted, however, that even though the center of pressure should be shifted towards the windward eaves, if the pressure



STRESSES—POUNDS— {C. Compression / T. Tension}

TRUSS MEMBERS		Top Chord					Bottom Chord				Web Members							Reactions	
		1	2	3	4	5–8	9	10	11	12–14	15	16	17	18	19	20	21–25	R_1	R_2
Nevada Experiments	(1)	C 2120	C 2050	C 1550	C 1060	C 1180	T 2630	T 2100	T 1580	T 1060	C 482	T 480	C 710	T 605	C 955	T 793	0	1440	527
	(2)	3180	3040	1980	1160	1180	3820	2640	1740	1060	1070	1060	1250	1070	1210	990	0	2370	527
Hutton's Form.	(3)	10150	9850	7450	5100	5680	12620	10080	7600	5070	2310	2300	3400	2900	4580	3800	0	6890	2532

FIG. 13.

varies as the ordinates to a straight line, as I assumed in case (2), Fig. 13, then the *total pressure* on the windward slope as well as $p\ m$ varies as the first power of the wind velocity and not as the square of that velocity. That follows if my experimental data are accepted, since the said total pressure W_2 for case (2) equals a constant times Pn, where Pn is the assumed uniform pressure per square foot involved in the straight line formulæ of my Fig. 8. No one discussing the paper remarked about that point, which it seems to me is the feature in which my tests differ most radically from those of Stanton and others. I still think the explanation lies in the fact that the windward wall of my wind house extended to the ground, shutting off the passage of air beneath the building.

Professor Smith remarks about a probable downward suction effect acting on the underside of my test roof, due to the open rear of the building. That sounds reasonable and I recently tried to measure the rarefaction of the air inside the test house with an aneroid barometer with the following results:

Wind velocity, M. P. H.	25	35	45
Inside pressure below outside in inches mercury	0.02	0.03	0.04

This was, of course, only an approximation, as 0.1 in. of mercury is indicated on the aneroid barometer by about 0.03 in. movement of the pointer. I used a reading glass to aid in estimating the position of the pointer. Mercury, 0.03 in. is equivalent to about 2.1 lb. per sq. ft. pressure, so that looks as if the inner suction effect amounted to something. The above was with the roof at less than 15° inclination.

I think that my tests clearly indicate that the downward normal component on the windward slope, including suction effect, is considerably less than that given by Hutton's and some other formulæ, and that the results obtained by Stanton, Irminger, and other experimenters indicate that the lifting force of the wind should be considered of equal, or perhaps greater, importance in roof design than the downward force, therefore demanding ample provision in the way of anchorage.

It is evident that my experiments have touched only a small part of the subject and that part not with complete satisfaction, but I hope they may prove of some value at least in inducing others to take up practical experiments along this line.

RUN OFF FROM SEWERED AREAS

L. K. Sherman, M. W. S. E.

Presented January 15, 1912, before the Hydraulic, Sanitary and Municipal Section.

In compliance with the circular issued by the Hydraulic, Sanitary and Municipal Section of the Western Society of Engineers, I present herewith some data on the run off from certain sewered areas in the south part of the city of Chicago. These areas are three in number, designated by the location of the outfall sewers as the 39th Street district, the Wentworth Avenue district, and the 92d Street district.

39TH STREET DISTRICT.

The 39th Street district includes the territory bounded in a general way by 33rd Street, 87th Street, Lake Michigan, and west to State Street or Ashland Avenue.

The area is 14,340 acres. The population in 1910 was 273,698, —an average of 19 per acre. The distribution of population, however, is not at all uniform. The north half is densely populated. Streets are generally paved. The tabulation of run off presented here is compiled from the pump records of the 39th Street pumping station for the year 1909. This was a year of excessive precipitation. The rainfall was 43.22 in., whereas the normal annual precipitation is 33.70 in. The territory is very flat, being practically level from north to south and sloping only 2 or 3 ft. per mile from west to east.

In Table 1 is shown the run off of the 39th Street district, arranged according to the amounts in cubic feet per second, and the corresponding 24-hour period for such amounts of run off or pumpage for each month of the year 1909. From this tabulation Diagram I was made. The curve marked "Rainfall" is platted to the same scale as the run off curve and the difference between the two curves, less the supply from the water mains, shows the absorption and evaporation.

WENTWORTH AVENUE DISTRICT.

The Wentworth Avenue sewer district is an irregular shaped area extending from 87th Street on the north to the outlet into the Calumet River on the south,—a distance of 5¼ miles. The north 2½ miles is about 2½ miles wide. The south part varies from one mile down to one-half mile in width at the outfall. The west part of the north half of the drainage area includes a steep ridge, the summit of which is 70 ft. above the east half. The surface along the east portion through which the main outfall sewer runs is nearly level.

Table I

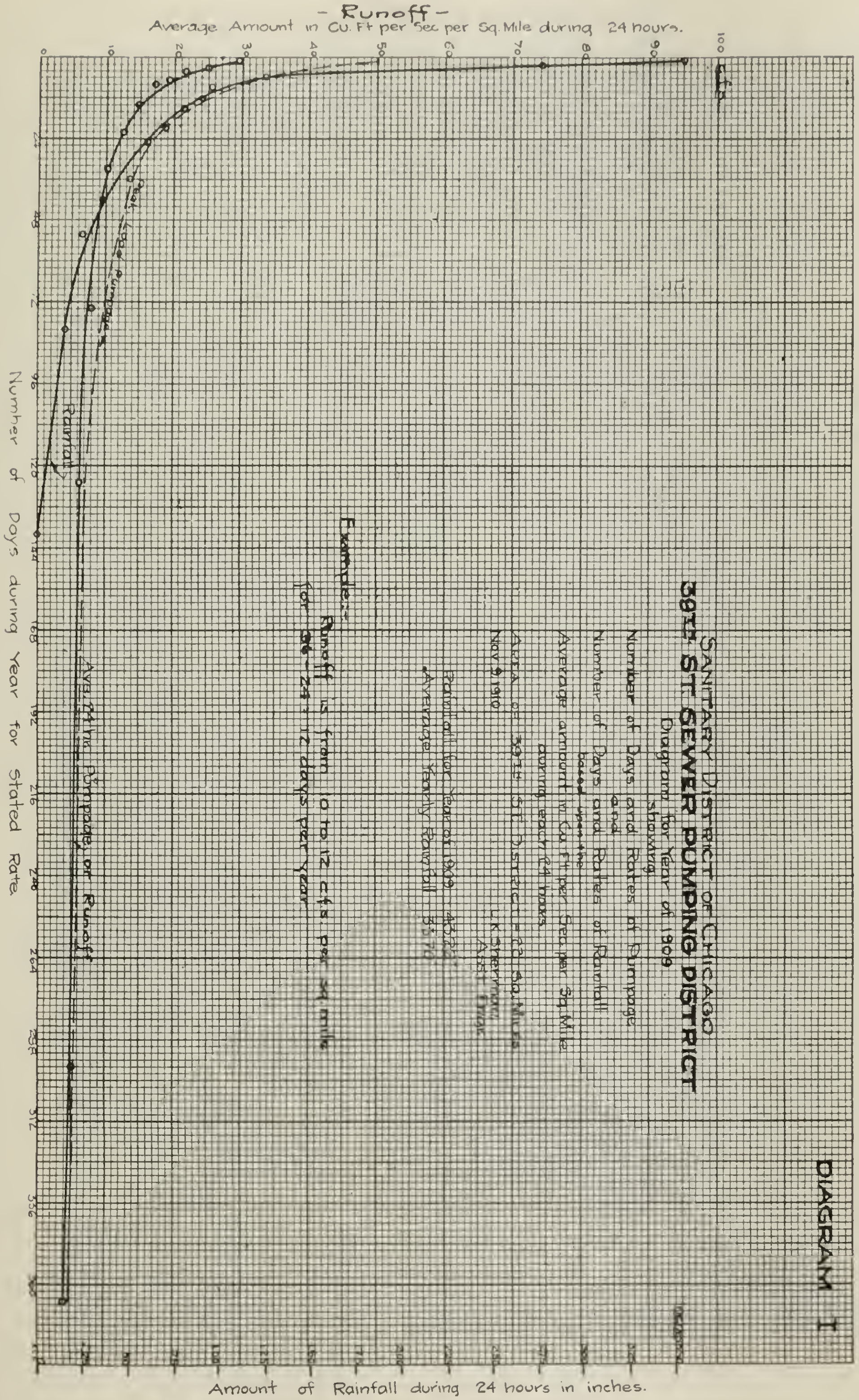
39TH ST. SEWER DISTRICT

Showing number of days and corresponding rates of runoff (pumpage)
For year 1909 —

Area of district = 22 sq. mi.

Total Runoff Cu. Ft. per Sec	1909 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total days	Minimum Runoff Days	Minimum Runoff Cfs per sq. mi.
76 to 100	19	3	12				6	2		13	9	5	69	365	4.0
101 to 125	9	12	12	10	8	15	17	20	23	14	13	18	171	296	5.14
126 to 150	1	5	6	7	12	3	2	3	1	2	5	4	51	125	6.27
151 to 200	2	4	1	4	7	9	3	3	4	1	1	2	41	74	7.96
201 to 250		2		2	3	1	1	1	1				11	33	10.21
251 to 300		1		1	1		1	1	1	1	1		8	22	12.50
301 to 350		1		1		2	1					1	6	14	14.76
351 to 400				1									1	8	17.06
401 to 450				2								1	3	7	19.32
451 to 500											1		1	4	21.60
501 to 600				1				1					2	3	25.00
601 to 700				1									1	1	29.50
Total days	31	28	31	30	31	30	31	31	30	31	30	31	365		

Maximum Run-off at Rate of 50 c.f.s. per sq. Mile.



- Runoff -
Average Amount in Cu. Ft per Sec per Sq. Mile during 24 hours.
Number of Days during Year for Stated Rate
Amount of Rainfall during 24 hours in inches.
Rainfall
Avg. 24 hr. Pumpage, or Runoff
SANITARY DISTRICT OF CHICAGO
39TH ST. SEWER PUMPING DISTRICT
Diagram for Year of 1909
showing
Number of Days and Rates of Pumpage
and
Number of Days and Rates of Rainfall
Average amount in Cu. Ft. per Sec. per Sq. Mile
during each 24 hours
Nov. 1910
L. K. Sherman
Asst. Engr.
Example:-
Runoff is from 10 to 12 c.f.s. per sq. mile
for 24 days per year
DIAGRAM I

Table 2

Wentworth Ave. Sewer District

Showing number of days and corresponding rates of runoff.
For year from August 1, 1910 to July 31, 1911.

Area of district = 8.28 sq. mi.

Total Runoff	1910					1911							Total	Minimum Runoff	
Cu Ft per. Sec.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb	Mar.	Apr.	May	June	July	days.	Days	C.f.s per sq mi.
3 to 5	19	12											31	365	0.48
5 to 7	8	4		6	3			1			9	8	39	334	0.72
7 to 10	3	13	27	22	27	23	13	17		9	13	16	183	295	1.03
10 to 15	1		3	2	1	7	10	12	16	17	4	3	76	112	1.51
15 to 25		1	1				3	1	11	4	1	2	24	36	2.41
25 to 50						1	1		3		3	2	10	12	4.53
50 to 75										1			1	2	7.55
75 to 100															
100 to 150							1						1	1	15.10
Total days	31	30	31	30	31	31	28	31	30	31	30	31	365		

Maximum Runoff occurred on Feb. 14-1911 at rate of 18.12 c.f.s per sq. mile

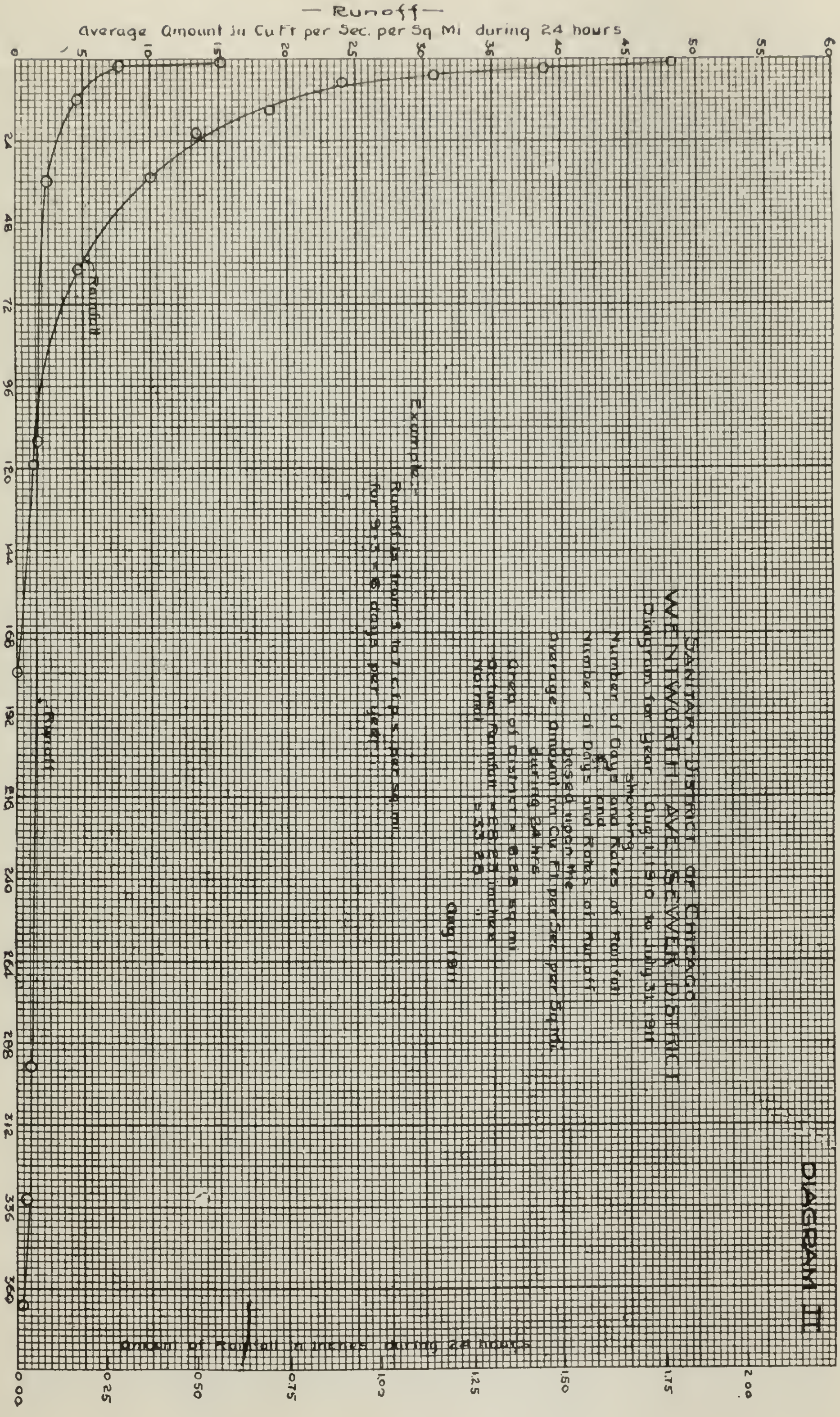

— Runoff —
Average Amount in Cu Ft per Sec. per Sq Mi during 24 hours
DIAGRAM II
SANITARY DISTRICT OF CHICAGO
WENTWORTH AVE. SEWER DISTRICT
Rainfall
Runoff
Example:-
Amount of Rainfall in inches during 24 hours

Table 3

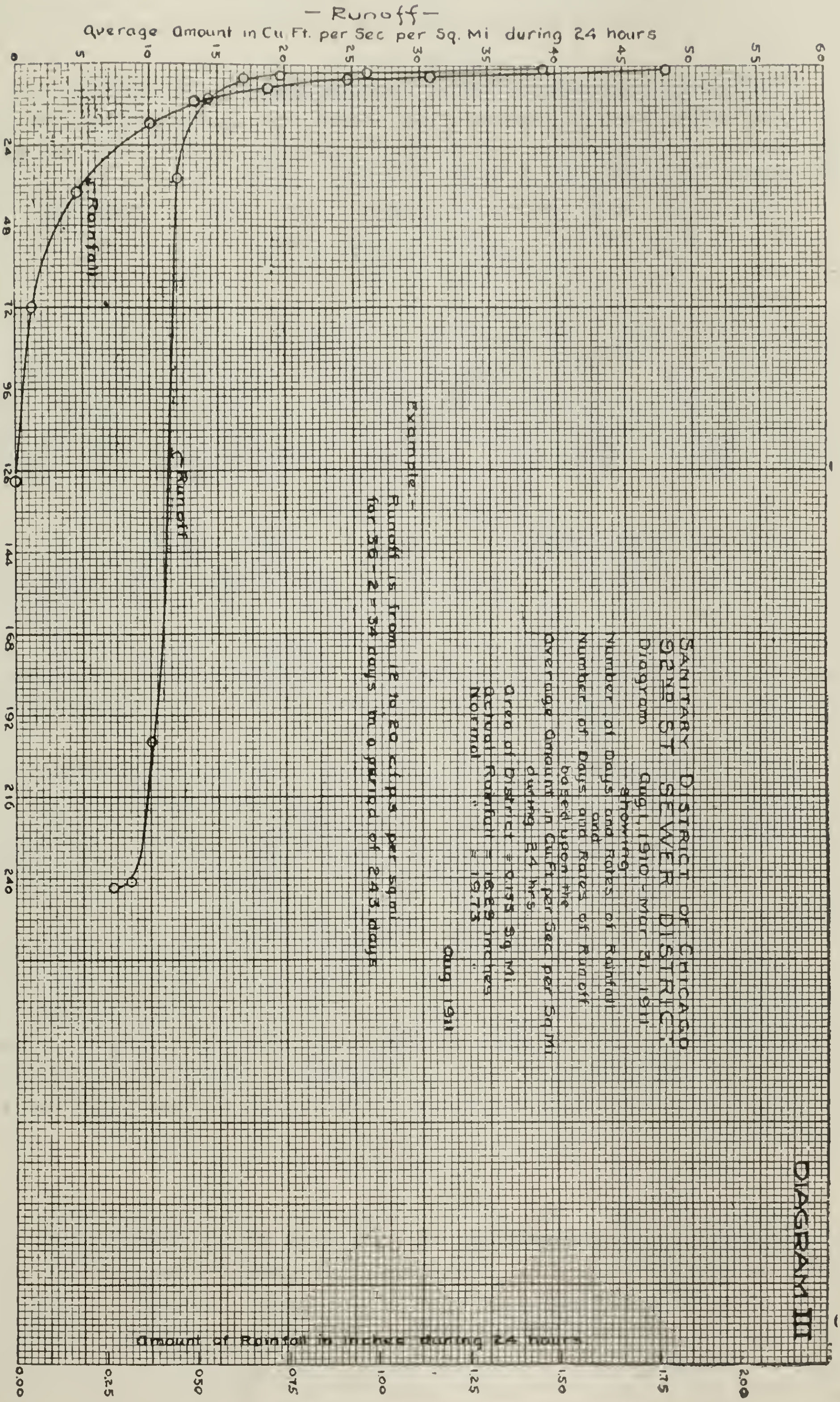
92ND ST. SEWER DISTRICT

Showing number of days and corresponding rates of runoff
For period of 243 days from Aug. 1-1910 to Mar. 31-1911.

Area of district = 0.153 sq. mi

Total Runoff Cu.Ft. per Sec	1910 Aug.	Sept	Oct	Nov.	Dec.	1911 Jan.	Feb.	Mar.	Total days.	Minimum Runoff Days	Cfs per sq mi
1 to 1.2	2								2	243	7.2
1.2 to 1.4	12	7	5		2	4	8	3	41	241	8.5
1.4 to 1.7	14	21	24	30	28	25	18	6	166	200	10.1
1.7 to 2.0	1	1					1	21	24	34	12.1
2.0 to 2.4	1		1		1	1	1	1	6	10	14.4
2.4 to 2.8			1						1	4	17.0
2.8 to 3.2						1			1	3	19.6
4.0		1							1	2	26.1
6.0	1								1	1	39.2
Total Days	31	30	31	30	31	31	28	31	243		

Maximum Runoff occured Aug. 23-1910 at rate of 78.4 c.f.s. per sq. mile.


— Runoff —
Average Amount in Cu. Ft. per Sec per Sq. Mi during 24 hours
Rainfall
Runoff
Sanitary District of Chicago
92nd St. Sewer District
Diagram Aug. 1, 1910 - Mar. 31, 1911
showing
Number of Days and Rates of Rainfall
and
Number of Days and Rates of Runoff
based upon the
Average Amount in Cu. Ft. per Sec per Sq. Mi
during 24 hrs
Normal = 19.73
Aug 1911
Example:-
Runoff is from 12 to 20 c.f.p.s. per sq. mi
for 36-2=34 days in a period of 243 days
Amount of Rainfall in inches during 24 hours
DIAGRAM III

The area of the Wentworth Avenue district is about 5,300 acres. The population in 1910 was 28,039,—an average of 5.3 per acre. It is a suburban district with but a small portion of paved streets.

The outfall sewer is 10.5 ft. in diameter. The record of run off was obtained by means of a sharp crested weir placed near the outlet of the sewer. The crest of this weir is 2.2 ft. above the sewer invert and is 8.72 ft. wide without end contractions. The observer read the weir gauge three times daily and also noted any high water marks on the gauge during intermediate periods. I think the discharge is correct to within 5 per cent.

Table 2 shows the run off of the Wentworth Avenue district arranged according to amounts in cubic feet per second, and the corresponding 24-hour periods for such amounts of run off for each month of the year from August 1, 1910, to July 31, 1911. The rainfall for this year was 28.23 in. as compared with the mean annual rainfall of 33.28 in. Diagram II was platted from Table 2.

92D STREET DISTRICT.

The 92d Street district includes an area of 99 acres in the center of the business district of South Chicago. The population in 1910 was 3,496, an average of 35 per acre. The surface is level, compactly built up and streets paved. Much of the land has been filled in for street grades. Table 3 and the corresponding Diagram III show the run off from this district for the period from August 1, 1910, to March 31, 1911.

The outfall of the 92d Street sewer is 3.5 ft. in diameter. The record of run off was obtained by weir gauge reading similar to the Wentworth Avenue sewer. The weir was sharp crested with top 1.1 ft. above the invert of the outfall and 3.16 ft. wide without end contractions except for a short period of time when a weir 30⅛ in. wide with end contractions was used.

The rainfall record given is from the downtown (Chicago) station of the U. S. Weather Bureau. While the amount of individual downpour on any one day between the downtown district and the South Side districts may be different, it is not likely that there is any material difference in the amount of maximum downpour, the annual precipitation or the number of days per year for any stated rate.

GENERAL.

Several detailed and elaborate analyses have been presented in recent years for estimating the amount of run off for sewered areas based upon records of rainfall. In the absence of the more direct data of actual run offs such methods may have to suffice the engineer in designing storm sewers or sewage pumping plants. For large areas in this climate the maximum run off will occur during a period of warm rains falling upon an accumulation of snow or upon an impervious surface of frost and ice. In

this case there is obviously no relation between the downpour and run off. The amount of run off depends not only upon the rainfall but upon evaporation, slope, and some ten or twelve other factors which have to be guessed at.

The writer believes that if the same efforts now expended in endeavoring to find a relation between rainfall and run off were directly applied to the collection and comparison of actual run off figures, a more definite basis for the design of sewers would be obtained.

Discussion.

Mr. Sherman: Preceding the discussion of the paper, I want to anticipate something that will probably be asked me, in regard to the method of weir measurements. In Fig. 1 an attempt has been made to picture one of the weirs with the gauges employed, and by the aid of that illustration I think I can explain how we measured the water. In this view the 10½ ft. Wentworth Avenue sewer outfall is shown. Inside on the invert we had a weir built, it being made water-tight. The crest is about 2 ft. above the invert, and just back of it is a vertical rod. That is the gauge rod, and the zero of that gauge is at the crest of the weir.

Reference to Fig. 2 will show how we worked out the sewer discharge. The invert of the sewer is represented at "a"; the crest of the weir, at "b," and the water surface coming over the weir, at "c." We took the length of the weir on the crest and used the Francis formula without end contractions, but that did not take care of the water that came through the triangular pieces on each side. Now, that is only a small part of the entire flow, but it is appreciable. We made this assumption in getting at that quantity: We divided the triangular piece on the sides into a number of parts—say three, and determined, first, the theoretical velocity of the lowest portion due to the head above it. We then figured the velocity of the next portion due to the head above it, just as if it were an orifice, and finally the top portion. Knowing these areas and these velocities, the discharge was computed, and the actual discharge was taken as 75% of the theoretical discharge. The only reason for taking 75% was that it was known that the discharge was not the full theoretical flow. Any error involved in the assumption is small.

Langdon Pearse, M. W. S. E.: In regard to the run off from the 39th Street district (Diagram I), the curve is computed for the actual 8-hour watches of flow. The peak is somewhat higher. I have also computed the actual hours of pumpage, figured for intervals of ten minutes and longer, but it is not essentially different from Diagram I.

C. B. Burdick, M. W. S. E. (Chairman): We are greatly indebted to Mr. Sherman for the data he has given in his paper. As he has said, the actual figures on run off from sewered areas

Fig. 1—Wentworth Avenue Outfall and Weir.

are of much more value than the speculative figures of such run off. It seldom falls to the lot of the engineer who designs sewers, to have the opportunity of measuring the run off from them after they are constructed. The sewer districts for which these figures have been given are quite unusual; very few cities in the country have such large sewered districts. The figures are remarkable in another respect,—the extreme lowness of the maximum run off. As the author has shown, the maximum run off of the 39th Street

district is only 50 cu. ft. per sec. per square mile. It is my recollection that the intercepting sewers of Chicago were designed,—or at least, if my memory serves me correctly, it was the recommendation of the commission which reported on them,—to provide for a flow of ⅛ in. rainfall per hour, all reaching the sewer. That would correspond to about 0.12 cu. ft. per sec. per acre, and unless my mental calculation is wrong, that would be somewhere in the neighborhood of 80 cu. ft. per sec. per square mile.

The maximum run off rate last year was about five-eighths of the capacity of the sewer. Fifty second-feet is a very moderate maximum run off rate, as almost any one knows who has had occasion to examine into the flows of sewers and of rivers. It is

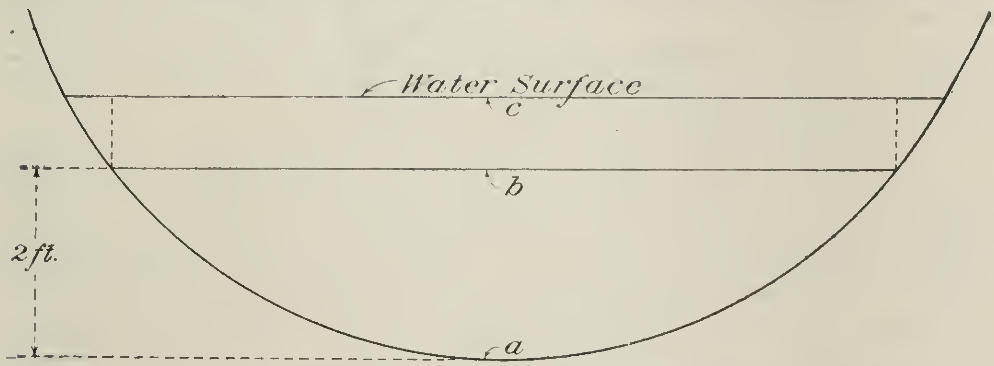


Fig. 2—Weir and Outfall of Sewer and Measurement of Area.

my recollection that probably three-fourths of the rivers of that drainage area in the central west would flow to exceed that rate. Out in the country, where there are no paved streets or anything of that kind, but where the slopes are much steeper than they are in the city of Chicago, actually greater run off rates occur than here. The reason is doubtless to be found in the very flat slopes that we have. Most cities require much larger run off rates in the proportioning of their sewers; in fact, as I carry it in my mind, many of them have ten times more than the allowance that would be indicated by this district as required in Chicago.

Another interesting fact is the minimum run off rate, or dry-weather flow, from the 39th Street district, four second-feet per square mile, with a population of 19 per acre, or 12,000 per square mile. It would be instructive, if data are available, to apportion this flow between its sources, water supply and ground water. The flow amounts to about 2.6 million gallons per square mile, or 215 gallons per capita, which is not far from the average water consumption of the city, although the consumption in that district may be somewhat different from the average. Data upon this point would be instructive. In well built up cities it is frequently found that the flow from the sewers on the average is in excess of the pumpage, in excess of the water supplied in the district. As I recall it, the commission which recently reported on the sewage

disposal of Milwaukee, figured an average sewage flow of 50% in excess of the water consumption, and it would seem that the 39th Street figure is somewhat less than that.

Mr. Pearse: In the report of our Chief Engineer (Mr. Wisner), dated October 12, 1911, is a table (printed below) which gives some of the drainage areas and dry weather run offs. From the standpoint of the Sanitary District, we are not so much interested in the storm curves as we are in the dry weather flow, for the purpose of sewage treatment, and the proper amount of sewage to treat before the discharge of the storm flow into the river. That is really our problem. I have made an analysis of the drainage areas that Mr. Sherman has shown, and of some others on which we had only two or three days' gaugings of the dry weather flow. (Table 4) For instance, we made an analysis of the 39th Street situation, and found that for 276 days in the year 1909 we had a flow of over 227 gallons per capita in 24 hours.

Last year I made inquiry of Mr. Phillips of the city water department and Mr. Baker, Assistant City Engineer, as to the probable use of water in that territory, and they could not tell me exactly, for they had made only a few pitometer measurements. I think the report of the Board of Public Works for 1908 shows, in certain areas, a use of water as low as 169 gallons per capita, per day, and in others something like 276, so it is quite probable that the run off is practically a little more than the use of water consumption. I believe the average pumpage of water in 1910 was 235 gallons per capita in the city of Chicago. From observation of pumpage records at 39th Street, it seems to me, that we are handling as much and usually more. We have to estimate the flow from the revolutions and the head on our centrifugal pumps. The rating curves are probably correct within 10%, and for the purpose for which these data will be used, they are probably sufficiently accurate.

There are other areas of interest. For instance, at Diversey Boulevard, with a population of 26 per acre, we found a dry weather flow of 238 gallons per capita daily. The measurements extended over two days. On Randolph Street, on the west side of the river, the flow was 348 gallons per capita daily, from a density of population of 47 per acre. At Robey Street, which enters the west arm of the South Fork of the river, to the west of Ashland Avenue, we had a flow of 169 gallons per capita in 24 hours, the density of population being about 15½ per acre. The sewers on Ashland and Center avenues had a very large run off, due to the use of water in the Stock Yards and Packingtown; we found it as high as 578 gallons per capita. At Center Avenue an absolutely dry weather flow of 20 cu. ft. per sec. per square mile occurred from that territory. The density of population is high,—36 per acre. The Wentworth Avenue district, as shown by Mr. Sherman, had a run off of 264 gallons per capita for 24 hours on what I took as a dry weather scale.

TABLE 4.

TYPICAL DRAINAGE AREAS AND DRY WEATHER RUN OFFS.

CHICAGO, 1910 and 1911.

Sewer Outfall	Drainage Area in Acres	Population Estimated 1911	Run Off Dry Weather				Density of Population Per Acre	
			Cu. Ft. Per Sec.	Cu. Ft. Per Sec. Per Acre	Cu. Ft. Per Sec. Per Sq. Mile	Gallons Per Capita Per 24 Hours		
Diversey boulevard (W.).............	90	23,550	8.65	0.0097	6.22	238	26.4	Aug. 15-17, 1911, 2 days
Randolph street (W.)...............	240	11,368	6.10	.0254	16.25	348	47.4	Aug., 3 days
Robey street (S.)..................	2500	38,728	10.1	.0040	2.58	169	15.5	June 1-3, 1911, 2 days
Ashland avenue (S.)................	980	44,581	23.2 *	.0237	15.1	338	45.5	May 18-20, 1911, 2 days
Center avenue (S.).................	660	23,463	20.9 †	.0317	20.3	578	35.6	May 16-18, 1911, 2 days
Thirty-ninth street pumping station....	14340	285,900	140. §	.0098	6.25	318	20.0	
			100. ‖	.0070	4.46	227		
Ninety-second street	98	3,666	1.84	.0188	12.	325	37.4	209 days Aug. 1, 1910 Mar. 31, 1910
Wentworth avenue (S.) (Calumet)....	5300	30,464	12.4	.0023	1.5 ‡	264	5.8	Aug, 1, 1910 July 31, 1911 253 days

*Daily variation average 8 A. M. to 8 P. M. 28.5 c. f. p. s. contains large amount of industrial waste.
8 P. M. to 8 A. M. 18.6 c. f. p. s.

†Daily variation average 8 A. M. to 8 P. M. 25.7 c. f. p. s. contains large amount of industrial waste.
8 P. M. to 8 A. M. 17.0 c. f. p. s.

‡2.4 c. f. p. s. per sq. mi. occurred 329 days in the year.

§This run off or more for 76 days in 1909.

‖This run off or more for 276 days in 1909.

On an average, I believe that for most of these districts about 300 gallons per capita per 24 hours will cover probably the entire average pumpage for a year, and will also represent a fair proportion or a fair amount to consider for the actual treatment of the sewage. Over that, we could probably afford to divert into the river direct without much, if any, treatment. Of course, at present the 39th Street flow is being pumped into the Stock Yards slip, and nothing is going into the lake. We expect to pursue that policy there always, and treat the dry weather flow and a proportion of the storm flow. On the sewers entering the river proper we shall probably treat the dry weather flows up to 300 gallons per capita and above that divert direct. Such was the point of view from which I looked at the problem; that is, first, what the dry weather flows would be, and then the maximum flow that might occur, of interest to the designer of the sewer.

The method used by Mr. Sherman, of having his points taken three times a day, is of further interest. It is probable that in looking for the peaks of curves a few points may be missed. That is, we have found at 39th Street that we are likely to get a heavy storm early in the morning. The worst one I have seen in that locality appeared about three o'clock in the morning, and before the men could get the additional pumps started, the water had backed up nearly to datum in the sewer proper. We had to put our screw pump into service to hold the water down. This is unusual, however, because there is sufficient capacity in the four centrifugal pumps to carry practically any storm flow we may have; that is, any flow of which we have a record. This simply shows that the peak point, if it comes in the middle of the night, may not be recorded.

Mr. Burdick: I assume that there is considerable storage room in that sewer.

Mr. Pearse: The pumping engineer operates the station in such a way that he has storage; that is, he figures on keeping down, I think, to a flow of about 5 to 6 ft., in a 16 ft. sewer. By allowing this, he figures that if there is a storm coming he has 2 to 3 ft. storage anyway and can in that time swing in his units. Usually the engineer has adequate warning, but at night when he cannot see the condition of the weather, it may happen that the gauge that indicates the water level in the sewer, may jam, and he gets his first notice by the howling wind outside or a heavy rain storm. As the area is so large I believe rains frequently occur in certain portions which the man at the pumping station never knows of, and he has to feel his way by the condition of the sewer flow.

I might add, in this connection, that our Board of Trustees has appropriated the sum of $2,000 to expend for the installation of rain gauges in the Sanitary District and certain automatic gauges at the sewers, to secure more adequate data over a wider

range, for use in our office. I presume the data will be published for the benefit of the profession, and it ought to be very interesting. At present there are only two rain gauges in the entire Sanitary District. One was recently installed at Evanston. Prior to that time there was only the one at the Weather Bureau in the Federal Building. We hope to install six automatic gauges and get some idea of the distribution of rainfall on the different water sheds.

C. C. Saner, ASSOC. W. S. E.: Some time last fall at Evanston we established a tipping-bucket rain gauge. Later on we placed a weir in the Davis Street sewer—a 4 ft. brick sewer which drains an area of 420 acres. The streets of the district drained are all paved, and the population is 6,000. The district includes the principal business streets of Evanston.

For measuring the flow over the weir we have established a Bristol automatic water level gauge on which the charts are changed every 24 hours. The dry weather flow in this sewer is about 216 gallons per capita, which checks very closely with the water consumption during December.

When cold weather began, it was necessary to bring in the tipping-bucket rain gauge, so that it has been impossible to compare the rainfall in the sewer with the precipitation.

In regard to a gauge reader reading three times a day,—7 A. M., 12 M., and 6 P. M.,—I have a record which shows that there were three storms during the night after 6 P. M. and before 7 A. M. The gauge reader would have seen on the gauge that the level of the water had been up, in this case, to 18 in. He would have had no means of telling the length of time of this storm, which in this case was 4 hours. Also, he would have missed the storm before and the storm after the large one. As soon as warm weather begins, our tipping-bucket rain gauge will be placed in service and we will then begin to secure storm records and run off records which we can compare, and which I hope to place before the Society.

Mr. Burdick: It is interesting to note the use of a recording gauge in a sewer. I was not aware that it had been tried. Doubtless it is quite important—especially when attempting to get at the average flow of the sewer—to have something in the nature of a recording gauge. This evening I had occasion to examine some curves showing the variation in the hourly rate of delivery of dry weather flow at different times of the day in various cities, and was impressed with the uniformity of the curves in the various cities. The curves were plotted as percentages of the averages, and with considerable uniformity the sewage flow ran from the neighborhood of 60% during the night time to 170% in the hours of the early forenoon; the flow then dropped to 60% again, with some short rises very late in the evening.

In attempting to estimate the dry weather flow, as we some-

times have to do in a city of considerable size for a special purpose, such as pumping or sewage purification, our custom has been to take hourly observations at some particular place for several days At the same time, observations are taken in different parts of the city in different sewers and are corrected for the hour of the day at which they are taken. The endeavor is to get at a total average for the entire city.

W. S. Shields, M. W. S. E.: Has there been any measurement of seepage in the 39th Street conduit?

Mr. Burdick: Mr. Shaw, can you tell us about that?

W. A. Shaw, M. W. S. E.: As to the seepage in the 39th Street conduit, I cannot give definite information. During the construction of the 39th Street conduit a No. 8 direct-connected centrifugal pump was installed at the northern terminus of the conduit, near the present site of the 39th Street sewerage pumping station. As the construction of the conduit proceeded south, the amount of seepage water increased. When the work reached 73rd Street, about 4¼ miles from commencement, the seepage was about what the No. 8 centrifugal pump would properly take care of.

In figuring the capacity of 39th Street conduit, a value of 0.018 was assumed for N in Kutter's formula. Mr. MacHarg, Consulting Engineer, was somewhat in doubt as to using the formula with N equaling 0.015 as is the general custom. I will ask Mr. Sherman if, in his investigations, he has taken any data in the territory north of 73rd Street? At 73rd Street there is the Jackson Park pumping station, which takes care of the territory from 73rd Street to 87th Street. That territory is more generally built up and the streets more generally paved than south of 73rd Street. Probably you would ascertain facts from this territory more nearly as to conditions that eventually will come about in the entire territory of the district drained by the 39th Street conduit.

Mr. Sherman: Up to the present time we have not taken any separate data at the Jackson Park station. The data we have represent the entire 22 square miles of drainage area averaged up, including, of course, this Jackson Park station. I think it would be a good thing to take up the records of that station.

Mr. Pearse: I have taken up the question of the pumpage at the Jackson Park station, and found it impossible to determine as the pumps have not been rated. The record is very crude, indeed, and of no value compared to that at 39th Street.

Mr. Burdick: In reference to the seepage of water in the sewers, it might be well to add to what Mr. Shaw has said that it is almost certain that the seepage at the present time is very much less than what he stated. If I understood him correctly, he stated that it was as much as a No. 8 centrifugal pump would take care of.

Mr. Shaw: The capacity of an 8 in. pump is usually about 2,000 gallons per minute.

Mr. Burdick: That would be about five second-feet. The

seepage into this sewer is doubtless much less now, as in construction the storage of water in the sand adds greatly to the normal flow, and this storage is largely drawn upon in the pumping incident to construction. On the other hand, there now reaches the pumping station the seepage from many miles of old sewers throughout the district that was not pumped during the construction of the interceptor.

Mr. Pearse: I believe Mr. Burdick is confusing the seepage of 5 cu. ft. per sec. with the run off of 5 cu. ft. per sec. per square mile. The comparison is really 5 (seepage) to 112 (run off) cu. ft. per sec. From that it would appear that the seepage is less than the probable error in estimating the pumpage at 39th Street.

Mr. Shaw: I think Mr. Burdick is right, in assuming that the seepage decreases as the sewer becomes older; as a matter of fact, during the time the conduit was being constructed the seepage did decrease. For a distance of about 7,000 ft. the conduit was constructed along the shore of Lake Michigan, and for about 2,000 ft. of this distance the conduit was constructed through the shoal water of the lake. The proximity to the lake would naturally tend to make an unusual amount of seepage, but as time elapsed the sand apparently filled in the voids in the brickwork and seepage decreased.

Mr. Pearse: Was most of the sewer in sand?

Mr. Shaw: As I remember it the inside of the bottom of the conduit at 39th Street was —19.69 and the clay at that point was about —12. The clay runs comparatively level from 39th Street to 53rd Street. From 53rd Street south to 73rd Street there is a gradual rise in the elevation of the clay. The clay at 73rd Street was at an elevation of about —4 or —6. The top 6 or 8 ft. of excavation was yellow water-bearing sand. Between the water-bearing sand and the clay, there was what is sometimes called quicksand, which is a blue, very hard and compact sand. In its original state, while being covered with water-bearing sand, this blue sand is comparatively dry. During construction it was necessary to allow the water from the yellow sand to pass over the blue sand. This caused the blue sand to assume and have all of the appearances of quicksand, and a casual observation would lead any one to believe that the blue sand was highly water-bearing, but as before stated, the blue sand has comparatively no water in it. Therefore, what seepage there may be from ground water comes from the stratum of yellow sand on top.

Mr. Sherman: When I began to install these weirs at 92nd Street, the Sanitary District at that time was not as well educated as it is now to the value and necessity of getting these observations. I am glad to see that Evanston realizes the value and importance of making such observations, and that Chicago and the Sanitary

District are going to continue the work, and also install self-recording gauges. I will admit that this is a great improvement over the method of collecting the data that I have been using where I had these weirs. However, in regard to Mr. Saner's point, I do not think that the value of our observations are as far away from the facts as Mr. Saner might conclude, by reason of omitting certain peak flows. We instructed our gauge readers to always note carefully the high water marks on the gauges. These marks were always very distinct and perceptible whenever there was a peak flow during the night over the weir. The marks were, I am quite sure, very well noted, so I feel that while the results were perhaps not as accurate as self-recording gauges might have given, they are, nevertheless, a fair index of what happened.

It has occurred to me that it is perfectly feasible to measure the outflow of sewers which have an outfall above the stream or water into which they discharge, without putting in any weir. The only reason for putting in these weirs is that we have no formula, no coefficient for computing what the discharge is without a weir. Nevertheless, the outfall from a sewer invert directly into the water below it is just as perfect a weir and just as good a device for measuring the flow, as a sharp-crested weir, if we have the coefficient for that form of an outfall. I think this is something which the universities could take up, in the way of thesis work. In a laboratory, the coefficient for flow from the outfall of a sewer could be determined. There might be cases where installing a weir would, under certain circumstances, back up the water to a serious extent.

Mr. Burdick: I can readily see how the end of the sewer makes a good weir, once you have it calibrated. One difficulty about doing any laboratory work of value to calibrate such weirs is that each sewer has a different velocity of approach. It might be possible to make a formula that would take that into account, as in the weir.

Mr. Sherman: Two points of elevation above the outflow rather than one, might be required.

Mr. Burdick: Possibly. But there are a great many ways that one can get at the quantity of water flowing in a sewer or river or elsewhere, and even the most imperfect weirs are much more accurate than many people realize. Recently I had occasion to make some rough estimates, for a special purpose, of water going over a dam with a very irregular crest. Afterwards, in making more exact measurements, I found the preliminary estimates were really more accurate than I had supposed. Even an imperfect weir is, I believe, more useful than ordinary observations of width, depth, and velocity in approximating flow.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS.

Extra Meeting, March 25, 1912.

An extra meeting of the Society (No. 780), being a joint meeting of the Electrical Section, W. S. E., and of the Chicago Section, A. I. E. E., was held Monday evening, March 25, 1912.

The meeting was called to order at 8.20 p. m., Prof. P. B. Woodworth presiding, with about 60 members and guests present.

The chairman introduced Mr. H. F. Smith, of Lexington, Ohio, who read his paper, "Notes on Producer Gas Power." This was illustrated by a number of lantern-slide views.

Some discussion followed from Prof. Woodworth, Mr. S. Montgomery, and the author in closure.

Meeting adjourned about 10:15 p. m.

Regular Meeting, April 1, 1912.

A regular meeting of the Society (No. 781) was held Monday evening, April 1, 1912. The meeting was called to order by Mr. W. W. Curtis at 8:25 p. m., with about 50 members and guests in attendance.

Mr. Onward Bates, Past-President of the Society, was introduced, who presented his paper on "Arbitration." Discussion followed from the chairman, and Messrs. W. B. Jackson, T. L. Condron, M. K. Trumbull, C. F. Loweth, W. E. Symons, Alderman W. J. Pringle, W. J. Crumpton, G. H. Bremner, C. B. Lewis, J. N. Hatch, C. K. Mohler, with further remarks from the chairman and the author in conclusion.

Meeting adjourned about 10:40 p. m.

Extra Meeting, April 8, 1912.

An extra meeting of the Society (No. 782)—the Bridge and Structural Section—was held Monday evening, April 8, 1912. The meeting was called to order at 8:20 p. m. by Mr. William Artingstall, at the request of Mr. F. E. Davidson (chairman of the Section), who was obliged to leave the meeting. About 45 members and guests were present. There being no business before the Section, Mr. F. A. Randall was introduced, who read his paper on "Test of Hard Pan at New Cook County Hospital." Mr. Edwin Hancock followed with "Results of Tests of Bearing Power of Moist Blue Clay in the Loop District, Chicago." Mr. W. L. Cowles presented a mathematical paper on investigating the lateral pressure against a vertical surface by a vertical load at a given distance from that surface. These papers were illustrated. The Secretary read, for Mr. Davidson, his remarks on the subject of "Foundations."

Discussion followed from Messrs. T. L. Condron, J. W. Pearl, O. H. Basquin, C. K. Mohler, J. T. Walbridge, F. L. Stone, and the chairman.

Meeting adjourned at 9:55 p. m.

Extra Meeting, April 15, 1912.

An extra meeting of the Society (No. 783)—the Hydraulic, Sanitary, and Municipal Section—was held Monday, April 15, 1912. The meeting was called to order at 8:25 p. m., Mr. C. B. Burdick, chairman of the Section, presiding, and with 35 members and guests in attendance.

The topic for the evening was a discussion of the relation of the State to the practice of engineering. After a few words of introduction by the chairman, Mr. Paul Hansen, Water Survey Engineer, Urbana, Illinois, read his contribution. Discussion followed from the

chairman and Messrs. Langdon Pearse, J. W. Alvord, Andrews Allen, F. L. Stone, L. K. Sherman, A. N. Johnson, Ernest McCullough (by letter), Paul E. Green, J. G. Gabelman, and J. N. Hatch.

Meeting adjourned about 10.20 p. m.

J. H. Warder, Secretary.

BOOK REVIEWS

The Width and Arrangement of Streets. A Study in Town Planning. By Charles M. Robinson. New York: Engineering News Publishing Co., 1911. Cloth; 6 by 9 in.; pp. 200, including index; 43 illustrations. Price, $2.00 net.

This is a pleasantly written book that contains some excellent hints as to town planning, with illustratios of what has been done elsewhere, whether in this country or Europe. The subject has its limitations, however. Suppose a town or village has had some thought given to laying out the streets and building lots; it frequently follows that a portion originally intended for residences may change with a conversion toward commercial or manufacturing interests, when it may be necessary that the streets be widened to meet the increased traffic demands. We will all agree with the author that among residences where there is but a moderate amount of wagon or carriage transit the streets may well be made much narrower than is frequently the case. As the cost of street paving is based on the square yards, a wide roadway necessarily costs more per linear unit of frontage and frequently this cost is a severe tax on the property abutting thereon. This is not advocating the lessening of the width between the houses, which space should be ample to insure plenty of light and air. Here it is that the broadening of the sidewalk space is desirable, which may be used for lawns—if that is not too grand a word for such small plots—or for flower beds and trees. Such beautification is valuable as increasing the feeling for one's home, and has a decided aesthetic effect.

For a situation where the natural land is somewhat hilly, it is often desirable to lay out the streets in curved lines; but on a flat plain, as in Chicago, many prefer the more rectangular plan, with the alignment of the streets having a definite and well-known relation to the cardinal points of the compass. By this arrangement it is easier to describe to a stranger any definite house or locality for which he may be in search. However this may be arranged, it is certainly good judgment to so pave the street to be in accord with its use.

Macadam pavement is very suitable among residences, if not a through route, subject to the destructive action of automobiles; in a newly planned subdivision, with comparatively few and scattered residences, economy will be served by narrow roadways. These could be widened at the expense of the parking at such time in the future when the traffic demands a broader roadway. Much has been said, at times, by those interested in city betterment, about *civic centers*, but the wisdom of such concentration may well be questioned. Many scattered centers throughout the extent of the urban territory, but conveniently connected together by desirable thoroughfares, would result in less congestion than at one municipal center.

The book contains some pleasing illustrations of good work, and also of other places, as examples of what should be avoided. W.

Municipal Improvements. A Manual of the Methods, Utility, and Cost of Public Improvements, for the Municipal Officer. By W. F.

Goodhue. New York: John Wiley & Sons. Cloth; 12mo.

This is an admirable little handbook of 207 pages, about 5 by 7 inches, with about a dozen line-drawing illustrations.

The author first takes up the subject of "A Sewerage System," with costs and ventilation, which is one of the most important of municipal improvements, and should be carefully considered along with A Water Works System. The author gives twenty-one pages to the latter subject, which includes some general tables of costs and an illustration of a typical pumping station drawing its water supply from a well and delivering it to an elevated tank; such a plant as suitable for a small town.

A short chapter is given to Street-Car Lines, and what should be the relations between the municipality and such a public utility. This is further elaborated in a chapter on A Municipal Franchise. Streets, pavements, sidewalks, curbs, gutters and bridges, when necessary, early demand the attention of the municipal officer, and in this work these subjects are well handled, and in a way to make pleasant and valuable reading. The advantages and disadvantages of different forms of pavements, as asphalt, brick, wood, macadam, and stone are set forth.

A chapter on Gas Consumption is followed by one on Street Lighting.

There is a short chapter on assessments for local improvements, which is of interest to property owners, as is another chapter on Building Laws and Ordinances. There is an interesting chapter on planning for a town hall, which would provide for the police and fire department—at least in part. The relation between the different officers of the town and their offices is shown clearly.

A chapter on Cleanliness and Public Health is full of good points. There are chapters on Public Parks, A Public Library, and A Morgue, which are worthy of consideration.

The final chapter, ten pages, relates to Municipal Ownership, and the author shows conclusively how and why it is not a success; that private management can secure more economical and better results than the employees of the municipality. W.

Assainissement Des Villes; Annuaire-Statistique International Des Installations D'Epuration D'Eaux D'Egouts. By B. Bezault. Masson & Co., publishers. 1911. Paris. 172 pages.

This book is a compilation of general laws relating to sewage disposal in the different countries mentioned, as well as a catalogue of the plants existing. The field covers Germany, Austria-Hungary, the Argentine, Australia, Belgium, Canada, Denmark, Egypt, Spain, United States, France, Great Britain, India, Italy, Mexico, Norway, Holland, Portugal, Russia, Sweden, South Africa, and Switzerland.

For many of the countries mentioned only a brief notice is given with a list of the cities. For several countries, such as France, England, and Germany, extended lists are given, the data, however, being restricted principally to the mention of the system of sewage disposal, the arrangement of the sewerage system, the population, volume of sewage treated, and the cost if obtainable. The data on the United States are singularly brief compared with those for England or the Continent, and in some cases decidedly incorrect. For instance, Washington, Pa., is said to have a population of 8,000 and an experimental plant. Only twenty-nine plants are mentioned in the United States.

The book is probably of service to an engineer who wishes to inform himself on the extent of sewage disposal in foreign countries.

L. P.

Paper Pulps From Various Forest Woods. Experimental Data and Specimens of Soda and Sulphite Pulps. Compiled by Henry E. Surface,

Chemical Engineer in Forest Products. The U. S. Department of Agriculture, Forest Service, Washington, D. C., March 7, 1912. Paper, 4½ by 6½ in.; 30 pages of text and tables and 55 leaves or samples of various kinds of wood pulp.

This little book is one of the Forest Products Laboratory Series, and is of much interest to paper-makers, showing what can be obtained from various woods in the way of pulps and papers and laboratory methods. At one time spruce wood was almost the only source for wood pulp, but the supply of this is becoming more and more scarce, and has led to experiments to see if there were other woods which could be used for this industry. In the text there is a table or list of the species, and their sources, used in these experiments, which include twenty-two different varieties of woods gathered from fifteen different States. The samples of paper shown are interesting to look at, exhibiting different colors and textures and conveying with the text much valuable information to an informed technician in this class of work.

There are eight pages of Table 2, "Record of experimental cooks using the sulphite process," and six pages of Table 3, showing corresponding facts when using the soda process. There is also an index to the pulp specimens exhibited in the book. The work was largely done at the Forest Products Laboratory, in cooperation with the University of Wisconsin, where the author is in charge of the section relating to pulp and paper. W.

Storage Batteries. The Chemistry and Physics of the Lead Accumulator. By Harry W. Morse, Ph. D., Assistant Professor of Physics in Harvard University. New York, the Macmillan Company. 1912. Cloth; 7½ by 5 in.; pp. 266, including index. Price, $1.50 net.

This book—the latest contribution to storage battery literature—has been read by the reviewer with a great deal of interest, and covers just what the title implies—"The Chemistry and Physics of the Lead Accumulator."

The author goes quite deeply into the chemical and physical theory of the lead cell and employs the ionic theory when explaining certain phenomena.

There are eighteen chapters and an appendix: Introductory and Historical. Electrochemical Fundamentals. Ions. Fundamental Cell-Reaction. Active Ions. Physical Queries. Energy Relations. Reactions at the Electrodes. Charge and Discharge. Capacity. Efficiency. Internal Resistance. Physical Characteristics. Plante Plates. Paste Plates. Diseases and Troubles. Commercial Types. Accumulators in General.

From a theoretical standpoint this work is a valuable addition to existing storage battery literature. Those chapters wherein the ionic theory is used to explain the characteristics of a storage cell should prove especially interesting to engineers. The chapter on Efficiency, though short, emphasizes some facts which are frequently overlooked by operating engineers.

Any one interested in the storage battery art should have a copy of this book. T. M.

The Metallurgy of Steel. F. W. Harbord and J. W. Hall. 4th ed. Enlarged and revised, with 51 folding plates, over 500 illustrations in the text, and nearly 80 photomicrographs of steel sections. Edited by W. Roberts-Austen. Philadelphia, J. B. Lippincott Company. London, Charles Griffin & Co. 1911. 2 vols., 8vo., cloth; 6 by 9 in.; pp. 933, and copious index. Price, $12.00 net.

The matter in Vol. I is divided into two parts—I, The Manufacture of Steel, and II, Finished Steel.

The Manufacture of Steel treats of The Bessemer Process, The

Basic Process, Manufacture in Small Converters, Chemistry of the Acid Bessemer Process, Chemistry of the Basic Bessemer Process, Gas Producers, The Open Hearth or Siemens Process, Basic Siemens Process, Production of Steel Castings, Production of Shear and Crucible Steel, Electric Smelting of Steel, Armour Plate Manufacture, and Direct Processes of Steel Manufacture.

The second section—Finished Steel—takes up the Mechanical Testing of Materials, Carbon and Iron, Influence of the Metalloids—Sulphur, Silicon, Phosphorus, Manganese, etc.—on the Physical Properties of Steel; Special Steels, or Steel Alloys; Heat Treatment of Steel; Microscopical Examination of Steel. Following these chapters is a chapter, or series of illustrations, on Typical Steel Plants, including the New Gary Works. Appendices of Specifications, of Steels, Tables, etc., with XXIX pages of index, conclude Vol. I.

The second volume of this valuable work takes up the subject of The Mechanical Treatment of Steel, which reviews the subjects of Reheating Furnaces and Handling Material at these Furnaces; Rolling Mills, their different types and the Operation of Rolling, Rolls for Three-High Mills, Special Mills, and Handling Material at the Rolls. An important matter in connection therewith is The Supply of Power, which includes the Producing of Steam, Rolling Mill Engines for Steam, Gas Engines, and Electric Driving. Under the head of Common Mills are included Section Mills, Plate and Sheet Mills, Rod Mills, and Continuous Billet, Bar, and Strip Mills. The author then describes the Handling of Material in the Stock Yard, and the Laying Out of the Mill; the Forging of Steel by the Steam Hammer and by Pressure, and Compressing Steel while Fluid receive due attention. Tube-Making, Wire Drawing, and Protecting Steel from Corrosion, conclude this comprehensive work. The great multitude of illustrations placed in the text, or when larger, printed on folding plates, add greatly to the value of the book. It is gratifying to one's national pride to note that the authors have given such frequent reference to descriptions and illustrations of "American Practice," meaning that developed and utilized in the United States. Mention should be made of the references to and illustrations of that wonderful aggregation of a modern steel works—the Gary (Indiana) plant. W.

LIBRARY NOTES.

The Library Committee desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

Chicago Bureau of Public Efficiency:
  Administration of the Office of Coroner of Cook County. Pam.
  The Park Governments of Chicago. Pam.

F. L. Anders, M. W. S. E.:
  Report of City Engineer, Fargo, N. D., 1911. Pam.

American Telephone and Telegraph Co.:
  Annual Report of Directors to Stockholders, 1911. Pam.

Milwaukee Bureau of Efficiency:
  Education and Publications. Pam.

EXCHANGES.

Brookline, Mass., Water Board:
  Annual Report, 1911. Pam.

Canada Department of Mines:
Report of Commission Appointed to Investigate Turtle Mountain. Pam.
Engineers' Society of Pennsylvania:
Directory, 1912. Leather.
New York Public Service Commission, Second District:
Abstracts of Corporations, 1910. Cloth.
Virginia Geological Survey:
Physiography and Geology of the Coastal Plain Province. Pam.
Tennessee Geological Survey:
Bulletin, April, 1912. Pam.
New York Public Service Commission, First District:
Proceedings, 1911. Cloth.
Ohio State Board of Health:
Annual Report, 1910. Cloth.
Massachusetts Railroad Commission:
Forty-third Annual Report, 1911. Cloth.
Engineering Association of the South:
Proceedings, January-March, 1912. Pam.
Canadian Society of Civil Engineers:
Charter, By-Laws and List of Members, 1912. Pam.

GOVERNMENT PUBLICATIONS.

U. S. Bureau of Education:
1912 Bulletins, Nos. 2 and 4. Pams.
U. S. Geological Survey:
Thirty-second Annual Report of Director, 1911. Pam.
Bulletins, 448, 466, 470, 484, 491, 493, 504, 505, 511, 512. Pams.
Water Supply and Irrigation Papers, 271, 278, 286, 287, 288. Pams.
Mineral Resources of the United States in 1910. 2 vols., cloth.
U. S. Department of Commerce and Labor:
Technological Papers of Bureau of Standards, No. 3. Paper.
Interstate Commerce Commission:
Statistics of Railways in the United States in 1910. Cloth.
U. S. Treasury Department:
U. S. Public Health and Marine Hospital Service. Cloth.
U. S. Department of Agriculture:
Paper Pulps from Various Forest Woods. Pam.
U. S. Bureau of Mines.
Technical Papers, 8, 10, 11. Pams.

MEMBERSIP.

Additions and Transfers.

G. A. Caproni, Salt Lake City, Utah................Associate Member
F. E. Downing, Chicago.........................Member
F. W. Greve, Jr., Lafayette, Ind....................Associate Member
James S. Harvey, Jr., Chicago.....................Junior Member
Geo. M. A. Ilg, Chicago, transfer Junior to..........Associate Member
F. H. Masters, Chicago...........................Member
Sidney J. Robison, Chicago........................Associate Member
Robert C. Schwarz, Chicago, transfer Junior to......Associate Member
James Sorenson, Chicago.........................Student Member
A. B. Whitney, Chicago, transfer Junior to..........Associate Member

Deaths.

James P. Coleman, April 13, 1912.
Walter K. Means, April 17, 1912.

Journal of the

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LIGHT TRAFFIC PAVEMENTS FOR BOULEVARDS, RESIDENCE STREETS AND HIGHWAYS

LINN WHITE, *M. W. S. E.

A. C. SCHRADER, ‡M. W. S. E.

Presented February 19, 1912.

The chairman, Mr. O. P. Chamberlain, in introducing the speaker for the evening, said:

"Probably in no branch of the work of a civil engineer has there been more progress made, more changes made, during the past few years than in the building of roads. We have learned, by experiment in road work, that what has been done heretofore by Telford, Macadam, and others is by no means the last word in proper road construction. The building of hard roads has progressed rapidly throughout the country in the past five years. There is perhaps no place, however, where the chance to experiment on new materials for binders, on new materials for wearing qualities for the road, has been as good as in the public service and particularly in the parks. It has long been established that a macadam road is not the proper one for heavy traffic, but in many respects it is the best road for light driving and for light traffic of all kinds. The difficulties experienced with macadam roads in the parks and on public highways during the past ten years have been augmented by the introduction of the automobile. Roads which we had regarded as good, serviceable roads for light carriage traffic have not proven satisfactory in automobile service, as we all know. This, again, is a service which is largely exemplified in our public parks."

LINN WHITE, M. W. S. E.

There probably have been pavement problems ever since man in any community felt the necessity of improved roadways. The Romans, and other old-world road-builders of both older and newer civilizations than the Romans, offered a solution of the problem by constructing a paving surface of massive blocks of stone in which the only concession to light traffic requirements was to lay the blocks with nothing but earth as a foundation. The result

*Chief Engineer, South Park Commissioners.
‡Chief Engineer, West Chicago Park Commission.

could not have been, at its best, what we now consider a light-traffic pavement. The elements of drainage, crown, resiliency, noiselessness, cleanliness, etc., apparently did not receive consideration. Some examples of pavements constructed along these lines, with comparatively large square blocks of stone on scarcely any foundation at all, may be found today in the older cities of our own country, although I am of the opinion that but few of them were ever built in America. More scientific methods of road-building were developed before many of our communities reached that stage of civilization.

The first historical, scientific improvement upon the heavy stone block pavements of the older civilizations was made by the French and English engineers during the time when the roads now almost universally known as macadam, were developed. In macadam, the principles of inter-support of the particles making up the pavement, resiliency, under-drainage, and protection of the roadbed from surface water, were first recognized; and this was the first scientific solution offered of the light-traffic pavement problem. It was so good a solution that for generations none better was offered. Other types of pavements were developed; stone blocks were improved on, brick was introduced, natural asphalt was discovered, and even so perishable a material as wood was utilized in improved forms of pavements such as the Nicholson; and latterly, the high-grade creosoted wood block pavements. Concrete was introduced in foundations and rules for drainage, grade, crown, etc., worked out. But in this development, as a rule only the needs of the traffic or business street, carrying what is generally termed heavy traffic, was considered. Macadam remained, *par excellence,* the pavement for residence streets, boulevards and highways.

Definition.—This leads up to the point of offering a definition of a light-traffic pavement. It must be suited to carry rapidly-moving pleasure-vehicles, the miscellaneous traffic of residence streets, and the infrequent heavy loads that may pass over any highway. It must be inexpensive and flexible in cost, simple of construction, but without loss of permanency. It must be dustless, noiseless, resilient, smooth, non-slippery, cleanly, and of agreeable color to the eye.

Macadam is inexpensive and flexible in cost, simple of construction, and non-slippery. It is not permanent, and is dusty and uncleanly. Compared to other pavements, it is less noisy than some, has a small degree of resiliency, is fairly smooth only when repaired frequently, and under certain conditions has an unpleasant glare in the sun. Thus, of ten conditions above imposed on the ideal light-traffic pavement, macadam possesses three, is lacking in three, and may be said to be neither good nor bad in the remaining four. Other pavements generally recognized as standard, such

as stone block, brick, creosoted wood block, and sheet-asphalt, are pre-eminent in some two or three points, but deficient in others.

Referring again to the earliest successful type of light-traffic pavement—macadam—and considering whether it should be abandoned in favor of some other improved type, it is well to consider its cost and present value to the community. In the older communities and towns, as a rule the larger portion of the highways and streets have been improved at some time with macadam which is gradually displaced with some more costly and efficient type of pavement. In some of our newer towns and cities which have sprung into full development within the space of a few years, this is perhaps not true. There is a period of development during which macadam serves a useful purpose, but such pavements as brick, wood block or asphalt, pushed by energetic promoters and sagacious real estate dealers, are planted directly on the almost untrodden native soil. Chicago, to use a local illustration, is neither very new nor very old. There are within the city limits in round numbers 1800 miles of streets that have been paved or improved in some manner so as to put them in a usable condition. Of this mileage, 600 miles are paved with macadam costing originally, say, $1.15 per square yard, or $15,000 to $20,000 per mile. The total original investment in macadam in Chicago then would be $10,000,000. This calculation is leaving out of the question streets that are only partially improved with slag macadam or gravel, of which there are many miles, and the public investment in which must be considered temporary. The public investment in well-built, completely-improved macadam streets, figured above, being $10,000,000, a pertinent question is, shall this be entirely lost as the pavement is worn out or when its character is no longer satisfactory, or shall it be converted into a practically permanent investment? Macadam is a comparatively costly pavement surface to maintain in good condition, and even with the best methods of maintenance it does not satisfy the higher and higher ideals of an enlightened community. It is also true that a time comes when it is no longer possible to maintain a macadam street. The cost, the time consumed in repairs, and the portion of the time the surface is in an unsatisfactory condition, become intolerable.

These are questions and conditions which the governing bodies of Chicago, the Park Commissions, and Board of Local Improvements, are facing. This is one phase of Chicago's light-traffic pavement problem. The three larger Boards of Park Commissions, namely, the South Park Commissioners, West Chicago Park Commissioners, and the Lincoln Park Commissioners, have offered a solution to the problem which it is the further purpose of this paper to describe.

In the effort to solve the problem in the least costly manner,

various binders have been applied to the macadam surfaces, with the intention of holding the particles in place, and stopping raveling and the formation of dust. These have all been bituminous in nature except comparatively small quantities of hygroscopic chemicals used for dust-laying alone.

Among the earliest use in Chicago of a bituminous compound on the surface of macadam, was in 1905, when what is known as Westrumite was used on the Midway in the form of a saponified emulsion. Its use was continued practically through the season, and, while reasonably efficient as a dust-layer, it was abandoned because it cost more than water-sprinkling, and added but little of bonding value to the macadam. A thin skin of oil-saturated material formed on the surface, and when it was broken through, the macadam beneath was found to be lacking in the moisture necessary to hold it together and it crumbled and disintegrated rapidly.

The use of oil, both neat and in the form of emulsions, was soon after taken up by both the Lincoln and West Chicago Park Commissioners, and, while much good resulted from its use, the results were generally similar to those obtained on the Midway alluded to above.

When the heavier grades of oil, or those asphaltic in character, were used, the cementing value was greater, but with none of these materials was the result permanent or satisfactory. The first apparent success was obtained by the use of a specially refined tar, sold under the name of Tarvia, used in 1906 on Michigan Avenue south of 22nd Street. It was applied hot at the rate of ½ to ¾ gal. per sq. yd., and was covered with a layer of screenings by the process which has since become well-known throughout the country. The result was promising, though in some cases the bituminous surface thus formed scaled off and left the macadam unprotected within a month or two. It was soon discovered that for good results it was necessary that the macadam be *penetrated* to a considerable depth, which required special preparation of the surface. The use of Tarvia and another similar product,—Taroid—also to a less extent, heavy road oils, was continued in the South Park district during the years 1906, 1907 and 1908, with varying success. Nearly a half million yards of surface was thus treated, the quantity used seldom exceeding ½ to ¾ gal. per sq. yd., and the cost averaging somewhat under 6c per sq. yd., where no new stone was used except the screenings or stone chips for a top dressing. The greatest obstacles to successful work were moisture, dust, and dirty macadam. To overcome dust and dirt, the road surface was swept and cleaned, and the macadam broken up by picks in the wheels of the rollers, and harrowed to bring the coarse stone to the surface, or new stone added. With this preparation it was still necessary to apply the bitumen only when the

macadam was dry. Sometimes this meant a wait of days and even weeks, with perhaps the street in the meantime barricaded. Experience taught that still deeper penetration with heavier gravity bitumens was advisable where the traffic was considerable, and that new, clean stone was better than old. Following these ideas, the first section of work done in Chicago after what is now recognized as correct penetration methods, was in August, 1907, on Michigan Avenue from 41st to 42nd Street. Here a specially prepared grade of Tarvia was used, of about 1.20 gravity at 60 deg. F., corresponding to what was soon afterwards put on the market as "Tarvia X." The quantity used was 1¾ gal. per sq. yd., and the cost approximated 31c per sq. yd., including 1½ in. of new stone. This quantity of bitumen can be successfully used only by getting a fairly deep penetration in a coarse, open layer of stone.

Of almost 500,000 sq. yd. of the above described work done in the South Park district during the three years of 1906, 1907 and 1908, only about 100,000 sq. yd are in use at this date, of which approximately one-third will have to be replaced by some other pavement in 1912. Wherever teaming traffic has been admitted the paving has entirely disappeared. The best remaining piece of penetration work in the South Park district is a piece of Tarvia pavement, about 34,000 sq. yd., in Jackson Park.

As an example of successful penetration work, mention should be made of a portion of the west drive in Lincoln Park, which was done in 1908 with the road asphalt known as Sarco. A layer of very coarse macadam stone, ranging from 2 to 3 in. in size, was provided and poured with the asphalt having a melting point of about 200 deg. F.; the surface was then finished with finer material. The cost was said to be about 75c per sq. yd. The paving is still in good condition. The difficulties and disappointments attendant on work of this sort by the penetration method forced the realization that better methods must be devised.

In 1908 the first surfacing of macadam was done by mixing bitumen with sand and stone before laying, and in this year about 10,000 sq. yd. were so laid in the South Park district, following some previous small experiments.

No satisfactory machinery was found available for mixing the paving material, except the large and comparatively expensive plants used for sheet-asphalt work, until in the spring of 1909 the Link-Belt Company, of Chicago, put on the market a portable asphalt mixing plant specially adapted to the sort of work proposed. Two of these plants were purchased by the South Park Commissioners, and in 1910 one each by the West Chicago and the Lincoln Park Commissioners. These four plants have been operated each season since their purchase, and up to date about 1,000,000 sq. yds. of pavement have been laid with them. Most of it has been on the old macadam already in existence on the boulevards and

park drives, thus offering a solution of the problem of preserving and utilizing macadam pavements. The results have been very satisfactory and the amount of repairs have been almost negligible.

The evident advantages of surfacing the macadam with paving material mixed before laying, over the penetration method, is in the uniformity of the product obtained and the ability to proceed promptly with the work during almost any reasonable weather. Whatever the character of bitumen used, the surface is not nearly so liable to bleed or become sticky in hot weather, nor glassy and slippery in cold weather. Its uniformity of composition, if the proportions are correct, is a safeguard against the occurrence of weak spots in the pavement and also against waving or rutting under traffic. Pavements made in this manner have been given the name of *bituminous concrete,* and standard specifications therefor under this name have been adopted by the Association for Standardizing Paving Specifications, which held its last meeting in New Orleans, January 8-13, 1912.

Briefly, the composition of the paving material, as laid in Chicago, has generally been six parts of crushed stone, four parts of sand, and from 8% to 9%, by weight, of bitumen, or, as it should more properly be termed, bituminous cement. Bituminous concrete is the logical name, because the theory of its structure and composition is the same as ordinary concrete, that is, enough of the mortar constituent to fill the voids in the larger aggregate, and enough cement to coat and bind together all the particles of the aggregate. It should be added that the paving mixture must, even more surely than other good concretes, be impervious to water, for if water penetrates it, the adhesion of the cement is weakened. If the bituminous cement used is an asphalt, the resulting composition is properly termed *asphaltic concrete,* and if tar is used it is *tar concrete.*

Most of the preceding remarks have been directed to re-surfacing and preservation of old macadam, but that is only because it is with this phase of the problem the Park Commissioners of Chicago have been mostly concerned. The same processes and materials are equally well adapted to use on new macadam or concrete base, and have been so used to a considerable extent elsewhere since the success of the Chicago asphaltic-concrete pavements has become known.

The paving mixture described above is of course of uniform composition throughout, the larger particles of stone being distributed through the mass, and the pavement made in one layer. The size of the largest particle of stone is about half the thickness of the pavement, which is generally made from 1½ to 2 in. No particular effort is made to grade the stone as to size, it being taken as it comes from the crusher, with the dust and screenings

removed. The sand is graded from say 1/10 in. down to dust because it is essential, as stated above, to get a well filled, impervious and waterproof mixture. The surface of such a pavement necessarily presents some irregularities in appearance. In certain spots more coarse stone will appear, suggesting the idea that the pavement is not entirely waterproof at such points. To insure the proper results and uniformity of surface it is the practice generally, but not always, to coat the surface of the pavement, after rolling, with a paint or seal coat of neat bitumen and finally cover it with a thin layer of stone chips or sand.

A variation of the above described method of construction which has been used to some extent in the South Park district and which promises good results is as follows:

The size and proportion of stone are reduced in the paving mixture intended for the wearing surface, and the pavement is made in two layers—a *wearing surface* and a *binder course* of comparatively large stone. The binder course may be coated with bituminous cement, or it may be laid without any coating. In either case it should be clean stone of practically one size (about 2 in. is best), which is lightly rolled after being spread in place until it is firmly set into the macadam base, but with free and open voids left between the pieces of the stone. The paving composition for the wearing surface is then spread and thoroughly rolled until forced into the voids of the binder course.

The advantages of this type of construction are that the strong stone of the binder course forms an effectual key between the base and wearing surface, holding it against shifting or rutting, even under the most adverse conditions, and the wearing surface can be made thinner, thus reducing the cost. Also it is more flexible as to thickness and cost and recommends itself for this reason, particularly for roadways not carrying an excessive traffic.

The one-layer bituminous concrete described above, depends mainly on its own composition for stability, whereas the two-layer pavement derives its lateral stability mainly from the binder course. In this respect, and in general form of construction, it resembles the usual form of sheet-asphalt pavement, and, indeed, may be considered a cross between it and the one-layer bituminous concrete.

Mention has been made of the use of portable paving machines used for laying the bituminous concrete pavement, and the question will naturally arise as to why this type of machine is necessary. It is not necessary, for the usual type of stationary asphalt paving plant can be used for a bituminous concrete pavement, but the advantages of the portable plants are that they are made in smaller units, the investment is much less, they can be operated with a smaller force, and adapted to smaller work. The whole operation can be conducted under the eye of one superinten-

dent and by one organization; there are no long waits between the plant and the street; the continuous delivery of material keeps every man in the organization working in the most efficient manner; and, in short, the cost of every item of expense connected with the operation can be cut to the minimum. Besides a comparatively small investment and minimum cost of operation, the paving material is delivered on the street in the best of condition without loss of heat or segregation of materials due to long hauls.

It is probably on account of these advantages of the portable plants, in part at least, that contractors with large plants equipped for sheet-asphalt work have never appeared as advocates of asphaltic concrete pavements. There are other reasons, too. It is not feasible or desirable to equip portable plants with apparatus for fluxing asphalt except at the expense of portability and simplicity. All stationary plants built along old lines are so equipped. The portable plants, therefore, open up the way for the use of a class of asphalts, or, petroleum compounds similar to true asphalts, which do not require fluxing, which are meritorious in the paving industry, but which are not controlled by the so-called paving or asphalt trust. The simplicity of operation of portable plants with ready-fluxed bituminous cements, opens up the mysteries of the paving business to any intelligent engineer or contractor, which is not to be encouraged by any proper minded trust.

As may be inferred from preceding remarks, the bituminous cements used by the Park Commissioners of Chicago have been ready fluxed and generally of that class of asphaltic or semi-asphaltic cements not usually classed as natural asphalts. Two exceptions to this, however, should be noted: The South Park Commissioners have used a small quantity of specially refined tar, and part of the supply of the West Chicago Park Commissioners has been an imported natural asphalt.

It is not the purpose of this paper to go into the differences between and respective merits of these various bituminous cements, as that is a large and deep subject in itself, and it is hoped it may be further discussed before this Society by those who have made a specialty of it. Suffice it to say that there are essential differences in the practical working of the different materials. High ductility is generally a characteristic of natural asphaltic cements and also of tars. Ductility in itself is of but little value, but it is taken to be indicative of valuable qualities, such as tenacity and adhesion. Ductility, however, indicates susceptibility to changes of temperature, which is manifestly an undesirable quality. On the other hand, compounded or manufactured asphaltic cements (thus named for convenience in distinguishing them from so-called natural asphalts) generally have low ductility and are not very susceptible to changes of temperature. An ideal bituminous cement would combine these two excellent qualities.

There is still another reason why many engineers and contractors have not been advocates of bituminous concrete pavements, and that is the fear of infringing certain patents that have been issued for what is known as the Bitulithic pavement—a bituminous pavement in which crushed stone is an important ingredient. This is an important consideration, as the legal decisions so far rendered on the validity and scope of these patents do not seem to be conclusive. The matter has been before at least four or five United States Circuit Courts, generally in the form of injunction proceedings. In cases originating in Chicago and Indianapolis, injunctions have been denied on the ground of no infringement. In New York City and in a case originating in Owosso, Michigan, decisions have been rendered in favor of the patentees. There are certain conditions involved in each case which differ from the other; for instance, in the Owosso case the contractors for the infringing pavement followed almost exactly the methods and specifications promulgated by the Bitulithic company, apparently inviting attack. This case in the lower court was decided against the patentee, but on appeal was reversed and an accounting for royalty ordered.

In the Chicago pavements no attempt was made to pre-determine or grade the sizes of stone, the idea being to proceed as in ordinary concrete work with stone as it comes from the crusher, the dust being removed, mixing it with the proper proportion of sand and cement. On these grounds the injunction was denied. The effect is that in the Chicago district, the one-layer bituminous concrete pavement described in this paper may be laid without infringement. In Michigan and New York there is at least danger, although the specifications in the respective cases are by no means the same.

The alternate two-layer pavement described herein is entirely different in principle, and in no sense can it be considered an infringement of the patents in question. It depends mainly on the binder course for lateral stability, and does not derive an internal or "inherent" stability from the proportion of coarse aggregate in its composition, which is the essence of the Bitulithic patent claims.

The cost of the pavements described is a matter of first importance, and can best be given, perhaps, in the form of a record of a particular piece of work, or of a season's work; certainly such a cost record is most conclusive. Some figures of this character of work done in the West Chicago Park district will be presented to the Society, which are indicative of results accomplished in the other park districts.

In general, it should be said that the pavements laid by the three Park Commissioners have not cost must over half of what any other equally satisfactory pavement of similar character could

have been obtained by contract. As nearly 1,000,000 sq. yd. have been laid during the last three years by the three Park Boards, one can easily figure that a saving of many thousand dollars has been made.

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Prior to the use of the automobile, a well constructed macadam pavement was considered a satisfactory roadway in our parks and on many boulevards, but the difficulty of maintaining it under heavy motor vehicles soon became apparent. Holes would be worn in the pavement with surprising rapidity, and even when repaired in the ordinary way, the continuity of the surface could not be maintained for any considerable length of time, necessitating frequent repairs and closing of drives.

Engineers seem to agree very generally that a better bonding material must be used, and that a bituminous cement is the material. Considerable latitude is allowed in the use of the bituminous cement, both as to manner of application and as to the physical and chemical characteristics of the cement used. No doubt each year's experience will add greatly to our information regarding the proper uses of this material under varying conditions—especially when careful records are kept of methods of construction, and analysis of materials used.

In the West Park system, the mixing method of applying the asphaltic cement to the mineral aggregate was used by means of a portable plant, of the same type as that used by the South Park and the Lincoln Park systems.

During the year 1911, 137,500 sq. yd. of asphaltic concrete pavement were laid in the West Park system with its own plant, at a cost of 61¼c per sq. yd. The average thickness of the pavement laid was 2⅛ in., and the cost includes all labor and materials used, preparation of base, repairs to machinery, and a depreciation charge of 25% of the cost of the plant. The capacity of the plant is about 1,000 sq. yd. per day for pavement 2 in. thick.

The following shows the average quantities of materials used in laying 100 sq. yd. of pavement as described above:

Crushed limestone	4.02	cu. yd.	@	$ 1.65
Limestone screenings	1.01	cu. yd.	@	1.65
Bank sand	1.74	cu. yd.	@	1.05
Torpedo sand	1.44	cu. yd.	@	1.55
Asphaltic cement	2000.	lb.	@	18.00 to $18.22 per ton.
Granite screenings	0.504	cu. yd.	@	2.90
Gasoline	3.6	gal.	@	0.10 ½
Kerosene	0.95	gal.	@	0.05 ½
Coal	480.	lb.	@	4.75 per ton
Wood	0.7	cords.		

The cost per 100 sq. yd. for laying and mixing was $16.40; the cost of preparing base was $3.60; and a general charge of $7.44 includes depreciation, plant repairs, moving plant, and idle time.

The cost, it is seen, is about one-half the charge contractors make for a sheet-asphalt, wearing surface 2 in. thick on a binder course 1½ in. thick laid upon an existing base.

During the past two years 232,000 sq. yd. of this pavement have been laid in the West Park system with one plant, and it is believed that the pavement will prove a durable and satisfactory pavement for a pleasureway, and one which can be laid upon existing foundations of macadam or concrete at a reasonable cost.

Mr. Lester Kirschbraun has served the engineering department of the West Park system for the past two years as asphalt chemist. I believe it would be of interest to engineers to hear from him upon the subject of asphaltic concrete pavement as far as he cares to discuss matters pertaining to sources of supply, the methods of manufacturing and refinement, and the technical specifications relating to asphaltic cement and bitumen.

Discussion.

Lester Kirschbraun: The failure of water-bound macadam roadways to withstand modern conditions of traffic led to the development of wearing surfaces, in which asphaltic cements and various bituminous compounds play a most important part. The successful building of roadways for park and light city-traffic, both from the point of view of serviceability and economy of construction, has been largely developed in recent years in Chicago and elsewhere. The experience of the engineers of the Park Commissions with the methods described this evening, and in particular the development of portable equipment with which such wearing surfaces may be economically and conveniently laid, has given impetus to the improvement of macadam roadways by the various park systems of the city. And this method of construction is recognized by engineers as the best solution of the road problem.

While this permanent construction has met the requirements of the traffic for which it was designed, there have been developed, through the popular need for good roads, many other cheaper and less permanent types of construction, in which bituminous binders are used. The demand for country and suburban roads has very largely increased the production and consumption of asphalts and other bituminous cements, and it becomes of much interest to inquire as to the origin and method of preparation of the various asphaltic materials upon the market.

Commercially speaking, there are two classes of asphalts,—natural and artificial; the former, as indicated, is a variety of solid natural mineral bitumen; the latter is artificially produced

from liquid mineral bitumen,—i. e. petroleum. It may be stated that the word asphalt is not used here in its scientific sense, for it has recently acquired a far wider meaning than its original significance. It was first applied to designate the European bituminous lime rock,—the natural mixture of bitumen and carbonate of lime which was the forerunner of the present asphalt pavement. The word asphaltum has latterly been applied to such natural bitumens as Trinidad lake asphalt. The enormous development and production of artificial products suitable for paving purposes, has resulted in a loose application of the word asphalt to a commercial significance embracing all solid bituminous products prepared from solid or liquid natural bitumen, such products being commercially useful for asphalt paving and for kindred arts.

Natural asphalt, or, properly speaking, asphaltum, has been known from earliest antiquity. Although deposits occur widely distributed over the globe, there are today but few sufficient in extent or so advantageously located as to be of commercial importance. Briefly stated, there are sources of natural asphalt in Venezuela, Trinidad, Mexico, Cuba, Egypt, Palestine, Asia Minor, Persia. In North America there are deposits of various solid bitumens in West Virginia, Oklahoma, Colorado, Utah, California, Texas, and in Athabasca. Many of these are of interest scientifically on account of their manner of occurrence or peculiarities of constitution, but it will be impossible to consider in this connection any but those sources which are commercially important to the paving industry in this country.

Probably the best known deposit of asphaltum, and the earliest recognized in the paving industry, is the Trinidad deposit located on the island of Trinidad, British West Indies. There are a number of deposts of asphalt upon the island, the principal one being that of Pitch Lake, so called because the deposit, occupying the crater of an old volcano, resembles a lake with its shore line of vegetation. Mr. Clifford Richardson, in his "Modern Asphalt Pavement" has fully described this deposit, the salient features of which may be given here.

The surface of this lake of asphalt is sufficiently hard to support a team in motion, although any solid objects at rest are gradually engulfed in the asphalt. The pitch is in constant motion to such an extent as to interfere with making borings or the running of levels. There is a constant influx of new material from a subterranean source, which raises the center of the lake slightly above the sides. Near the center of the lake, borings have been made to a depth of 135 ft. without reaching bottom, at which point the movement of the pitch was so great as to make it impossible to continue the borings. Mr. Richardson has estimated that the deposit contains at least 9,000,000 tons of pitch and is being replenished at the rate of 18,000 to 20,000 tons per year. The level of the

lake has been lowered somewhat by the withdrawal in recent years, of over a million tons of asphalt.

Crude Trinidad asphalt is a peculiar combination of water, mineral matter, and bitumen. The crude material contains about 30% of water, 40% of bitumen, and about 30% of mineral matter The bitumen, water and clay appear to be combined or emulsified in uniform proportions.

At certain points the lake pitch has overflown the crater and has spread over the contiguous land, producing various deposits called land pitch, which has become more or less hardened and freed from water by exposure. The land asphalt is of course from the same source, and of the same character as the lake asphalt, differing from it very slightly so far as chemical analysis shows. Much stress was laid at one time upon the slight differences between land and lake asphalt. The most that may be said, however, of these differences is that the land asphalt requires somewhat more and a better quality of flux oil than the lake asphalt, to produce the necessary softness for use.

West of the island of Trinidad, on the main land, is located the Bermudez deposit in the state of that name, in Venezuela. This deposit is also said to be in the form of a lake, and although very shallow it covers a wide area of swampy territory, to the extent of 900 acres. The deposit is apparently the result of exudation of tar or maltha springs, which has been hardened by the effect of exposure and climatic heat. These maltha springs are apparent at many points at the surface of the lake where the material exudes in a thick liquid condition. The material is softer than the Trinidad asphalt and is not emulsified with water or mineral matter. It is a comparatively pure bitumen and carries a small amount of non-bituminous portion, which occurs apparently through the entanglement and collection of vegetable matters by the soft pitch. Aside from the difference in hardness and the foreign matter with which the Trinidad and Bermudez asphalts are mixed, their bitumens have quite similar ultimate composition.

Still further west in Venezuela is located the Maracaibo deposit, about 50 miles inland from the Gulf of Maracaibo. There are a number of deposits in the vicinity and the asphalt appears to originate in maltha or tar springs as does the Bermudez deposit, the maltha having become hardened by exposure to a semi-solid, nearly pure, asphalt. The character of the material is quite different from the Bermudez asphalt, and it is recognizable by its particularly rank odor and the peculiar gummy nature of the impurities with which it is contaminated. The Maracaibo deposit has been of variable commercial importance, possibly on account of the difficulty of access, and its use has been limited in recent years to comparatively few localities.

On the island of Cuba there are a large number of deposits of

various kinds of asphalts, some of which were of commercial importance in the early days of the paving industry. Pavements were laid at an early date in the city of Washington, D. C., with asphalt from Cuba known as Bejucal asphalt, from a district of that name. This asphalt attained considerable commercial importance at one time, but in recent years it has disappeared from the market for the reason that the material occurs in comparatively small pockets, making it difficult and expensive to mine. There are a number of similarly occurring deposits upon the island, but the only one of large extent is located in the Pinar del Rio province about 40 miles west of Havana and about 5 miles from Mariel bay, from which the deposit takes its name. This material has been used in the United States for about ten years and has attained considerable importance. So far as is known to the writer, no account of this deposit has been given in any engineering literature, and for that reason this description is given in somewhat more detail than the better known deposits previously described.

The asphalt of these Mariel deposits is a very hard material resembling, in its crude state, bituminous coal. It contains about 56% to 60% of pure bitumen and about 40% of mineral matter. Like the Trinidad material, there is great uniformity in the proximate composition of the asphalt from different sections of the deposit. The asphalt occurs in immense seams and veins, some of which may be followed for several miles across country by their outcroppings. Certain of the seams lie horizontally, and have been worked by open cuts to a convenient depth, following the seams in their general trend. At other point of outcropping, the material has been obtruded in a vertical direction, and the excavation of open pits has followed the crude material downward. At one of these openings a pit had been excavated about 200 ft. in diameter to a depth of about 150 ft., where the vein had narrowed. At this point it again widened out as it extended downward. At the time of observation the pit had been sunk to a depth of approximately 250 ft., at which point the cost of timbering and pumping of water and the widening of the vein had apparently necessitated the further removal of material by driving horizontal galleries into the mass of the deposit. So far as could be ascertained, at no point had the depth of the deposit been gauged, but the various excavations and cuts apparently widened as they proceeded downward suggesting the possibility that at sufficient depth they would run together into a mother lode. Undoubtedly the deposit will yield much of scientific interest as it is more fully uncovered and studied. It has been impossible to obtain any sufficiently definite data for estimating the amount of asphalt in the deposit, but it is evident that the quantities are very large. Great amounts of this material are used in England.

Domestic deposits of natural asphaltum occur in various parts

of the United States, as has been before noted. In California there are certain deposits of large extent which were, in the early nineties, of considerable importance. Alcatraz asphalt was a well-known brand of such material. The development of the oil-asphalt industry in California made it commercially impracticable to work these natural asphalt deposits, and there is now no solid natural California asphalt upon the market. The most important and the only commercial supply of natural asphalt in this country is contained in the Gilsonite deposits of Utah. These are located in the eastern part of that state, near the Colorado line, in a comparatively limited area, and in a very inaccessible country. The veins are small and scattered about, and although the material does not occur in very large masses, there exists in the aggregate a large quantity of the Gilsonite. The latter is a hard black bitumen having a brilliant lustre and a conchoidal fracture. It is very brittle and is easily converted to a reddish brown powder.

The manner of occurrence of the Gilsonite indicates that it has been forced into fissures in the rock while in a semi-plastic condition. The veins are usually from a few inches to a few feet wide, and there are only a small number sufficiently large to be worked. The mining of Gilsonite presents many uncertainties, for, on account of the broken condition of the country the most promising prospects have a habit of pinching out suddenly. Disastrous explosions have occurred in the Gilsonite mines due to the fine Gilsonite powder from the dislodged masses. A very ingenious method of mining has been recently developed which consists of directing a jet of steam against the face of the veins. The unequal expansion of the material causes it to fracture and break off in masses.

Gilsonite appears on the market as firsts and seconds. The seconds are taken from the outer portions of the veins and are of a harder and more indurated nature. The seconds are physically distinguished from firsts by their more metallic lustre and by differences of fracture. Sometimes the distinction between firsts and seconds is merely one of size. There are great differences in quality in various Gilsonites which may be detected sometimes by appearance, but more often require chemical and physical tests for differentiation.

Gilsonite has some very desirable properties, making it of great value in other applications besides the paving art. It is compounded into roofing materials, varnishes, lacquers, rubber substitutes, and insulation compounds. It came into use in the paving industry about fifteen years ago, and for a time considerable quantities were used in that way, but quite recently the demand for it in other arts and its cost have somewhat limited its use in that connection.

The foregoing are the principal sources of natural asphaltum

now commercially available. By far the largest part of the domestic production, however, is artificial asphalt produced from various petroleum oils. The petroleum oils of this country are generally classed into three groups, known as paraffine, semi-asphaltic, and asphalt petroleums. The oils of the Pennsylvania field are paraffine base oils. Those of the Illinois, Kansas, Oklahoma, and Gulf fields are semi-asphaltic to varying degrees. The California oils are generally considered as strictly asphaltic. No artificial asphalt is made from the Pennsylvania or paraffine oils, but large quantities are produced from the oils of the semi-asphaltic and California group.

The earliest oil asphalt of this country was produced as a by-product from the straight distillation of California crude petroleums. The early asphalt so produced fell into disrepute on account of the careless manner of production, the lack of uniformity, and the inferiority of the product through improper methods of distillation. The demand for a better quality has induced improvement in refining methods, which has resulted in recent years in superior products being prepared especially for paving purposes.

There are at present two methods used in preparing oil asphalts, which methods are more or less adaptable according to the character of the oil operated upon. The first method is that of ordinary distillation of the crude petroleum with the use of saturated steam, the distillation being carried on until the solid or asphaltic portion of the oil remains. The distillation is carried on in large stills holding from 300 to 1,000 barrels of oil. Steam is injected into the bottom of the stills through perforated pipes to effect agitation and assist in the removal of the volatile oils. In the best practice, steam is also injected at the top of the stills to facilitate carrying off the heavy oil vapors, and to prevent their decomposition by condensation and dropping back into the hot oil The maximum temperature employed in careful practice rarely exceeds 700 deg. F. The material in the stills is brought to the desired consistency and run into cooling stills or through pipes cooled by oil used for succeeding charges. Sometimes the material from several stills is run into one large receiving still, where it is mixed with other batches and a greater degree of uniformity thereby attained. Aside from the kind of oil used, the value of the product of this distillation process depends upon the various means of preventing local overheating and decomposition, the amount and efficient distribution of steam injected, the time of the distillation, and the temperatures employed. There are commercial asphalts prepared in this way from California, Mexico, and Texas oils, and probably within a short time there will be products on the market from asphaltic oils derived from other sources.

The method of distillation described is more applicable to asphaltic base oils and is not generally employed with the semi-

asphaltic oils of the mid-continent field. Certain of these oils are not reducible to solid asphalts by this method on account of the excessive temperatures necessary, and the resultant decomposition attending the attempt to remove the paraffine and vaseline hydrocarbons which are largely present in such oils.

This brings us to a second method of preparation of asphaltic products by air blowing. That method has been developed particularly through an effort to utilize petroleum residuums of the character not reducible by the distillation process described. While directed particularly to such oils, the method is nevertheless most advantageously employed with the strictly asphaltic oils, of which the California oil is representative. Asphalts prepared by this method are commercially known as blown-oil asphalts.

In the preparation of blown-oil asphalts, petroleum residuum is the raw material. This petroleum residuum is prepared as the residue from the distillation of crude petroleums with steam through the lubricating oil fractions, and is continued in the best practice, with the removal of as much of the vaseline (if present) as can be accomplished without decomposition. The air-blowing operation is conducted in open kettles equipped with perforated pipes along the bottom. The residuum is kept at a temperature much below that at which normally it distills, and air is injected into the mass through the perforated pipes, producing a violent agitation and intimate contact between the residuum and air. The injection of air under these conditions produces, among other reactions, oxidation and condensation of the hydrocarbons of the residuum. The oil treated, gradually thickens and the process is continued until a product of the desired consistency is obtained. A significant characteristic of the process is that there is no material loss during the operation.

When residuum oils are used that are not sufficiently asphaltic to yield products of the quality desired, it is necessary to add asphaltic material such as Gilsonite—which is a hard bitumen—to the blown oil. By variations of the character of the residuum, and the amounts and character of solid base introduced, it is possible to produce a variety of products adaptable for many purposes. The blown-oil products possess, among other characteristics, a rubbery consistency and a desirable degree of inertness to temperature changes.

The quality of the product must be considered with reference to the purpose for which it is to be used, but it depends generally upon the asphaltic character and manner of distillation of the residuum used, and the extent of the blowing operation. These products have in recent years been used in the bituminous concrete pavements described.

It has been necessary to discuss the various commercial oil asphalts in connection with their manner of preparation. The

preparation of natural asphalts is comparatively simple. Gilsonite is a very pure bitumen and requires no refining before admixture with flux. Other natural asphalts are refined by melting in large kettles with steam or direct heat, thereby expelling the water and light oils and allowing the coarse mineral or foreign matters to separate out. Sometimes flux oils or other asphaltic materials are added in the process of refining. After thorough separation of foreign matters, the refined asphalt is drawn off into packages or moulds for shipment. Where the material is to be used at stationary plants, it is there tempered by the further addition of petroleum residuum or fluxing oils to the consistency desired. Where used in portable plants or under conditions which do not permit of this fluxing, the asphalt must be prepared at the refinery with the necessary amount of flux for the desired consistency. This flux is incorporated during the refining process, as described. The fluxing material may be petroleum residuums, liquid or semi-solid, prepared from oil previously described.

It will be seen from a survey of the many sources of asphalts the various methods of preparation, and the different fluxing materials with which they may be compounded, that the recognition of the properties of the commercial products is no simple matter. Rapid development of new sources of supply of artificial asphalts, the changes in the processes of preparation, and the recent tendency toward compounding of various materials under brand names, has complicated the problem of recognition of suitable products by the engineer and technologist to a degree requiring the most thorough knowledge of the chemical and physical characteristics of these materials,—considered especially in connection with their method of preparation for the market.

In considering the requirements for asphaltic products for bituminous-macadam pavements, it must be remembered that the conditions to be met are somewhat different than in sheet-asphalt pavements, consequently our experience with the sheet-asphalt pavements may admit of modification in certain connections. Bituminous concrete pavements are constructed of large aggregate, graded to contain minimum voids. This combination of mineral particles possesses a certain stability less dependent upon the binding medium, admitting thereby, under normal conditions of traffic, the use of a less cementitous binding agent than in the fine sand aggregate of the sheet-asphalt pavements. Further, the size and character of the stone particles enable the coating of same with thicker films of the binder. These considerations may modify the requirements of asphalt cement for the purpose in view.

It is possible to state briefly a number of requirements for asphalt cement for this purpose.

First, it must have chemical stability or weathering qualities, and the ability to permanently retain its physical properties.

Second, it must be well prepared, homogeneous, and free from decomposition products or evidences of overheating.

Third, it must be sufficiently cementitous to meet particular conditions of construction, climate, and traffic, especially retaining its binding value in summer to the extent of preventing displacement of the mineral aggregate.

Fourth, it should impart to the pavement a desirable degree of resiliency and sufficient malleability at low temperatures that the stresses of contraction may be easily relieved.

Fifth, it must be waterproof.

The purpose of specifications being to define, by tests, a desirable degree of these various qualities, it remains to consider in what way this may be accomplished.

Unfortunately it has been impossible to devise tests to measure directly certain of these qualities. For example, there is no very satisfactory way at present of measuring the binding value of these asphaltic products, and indications of this characteristic must be inferred from other tests. The problem is further complicated by the wide differences in character of various products described. As a matter of fact, it is almost impossible to cover, by a single specification, all types of asphalts without widening the various provisions to such an extent as to apply too loosely to any type. It has therefore been the practice to draw separate specifications where the various types of asphalt are considered, covering each type specifically.

Returning now to the individual requirements set forth, the first requirement of chemical stability is covered by suitable evaporation tests which determine the extent to which the material is volatile under standard temperature conditions. The hardening of the cement due to this volatilization and oxidation is determined by hardness tests with a penetration machine before and after exposure. The rate of hardening observed is an indication of the stability of the product. The temperature at which the asphalt gives off sufficient vapor to ignite,—determined as the flash test,—further indicates the stability of the material.

The second condition may be determined by tests whereby various solvents separate free carbon or decomposition products. The heat conditions of preparation of oil asphalts are also indicated by fixed carbon tests. With reference to fluxed natural asphalts, this test throws light upon the suitability and homogeneity of flux combinations, which latter may be more definitely gauged and checked by tests of ductility.

The third condition cannot at present be covered by a general test for binding values, but various other tests may be taken as indicative, to a degree, of this feature. In dealing with blown-oil asphalts, the extent to which the residuum used is asphaltic, or has been modified with asphaltic material, governs, directly the cemen-

titousness of the product. This is covered in the specifications by limiting a minimum specific gravity, and ensures the use of a heavy oil as the raw material and a maximum asphaltic character consistent with the other properties. Again, by limiting the maximum melting point permissible, with relation to a given hardness, a more asphaltic product is obtained, and one which is therefore more cementitous. With reference to other asphalts, the binding properties are roughly gauged by considerations of ductility with relation to hardness, bearing in mind the origin of the product examined.

The fourth condition, as well as the preceding, is controlled by prescribing a proper consistency of cement for the particular conditions to be encountered; malleability and cementing values are to an extent functions of consistency. The consistency of the product at extremes of temperature governs to a certain extent this resiliency of the pavement, although too close limits must be avoided in order not to sacrifice the binding qualites of the cement. The malleability of the pavement mixture at low temperatures may be tested directly. This characteristic of the pavement mixture is a function of the cementing ability of the asphalt, the consistency, the amount present, and its ability to elongate. Inversely it is a function of the viscosity of the cement.

As already indicated, the various properties of these asphaltic cements are so interrelated that variations in one property entail corresponding changes in other characteristics. For example, a certain inertness to temperature changes is desirable, but this quality, if too much emphasized, causes corresponding loss of cementing quality. It is not possible at this time to go into further detail regarding the significance of tests or the interrelation of various properties possessed by these asphalts. It is sufficient to say that in all these matters a happy medium must be sought, adaptable in each case to requirements of traffic, construction, climate, and the result which it is desired to attain. These are not matters capable of mathematic analysis and the definite setting of values, but are rather considerations of judgment based upon the understanding of various problems involved, and a knowledge and experience with conditions which have given successful results.

In conclusion, I would emphasize the necessity of scientific records of service given by products of known and predetermined characteristics. The haphazard method of construction of roads and pavements without knowledge of the character of the materials employed, is no longer followed, and engineers and technologists are rapidly acquiring closer control and more certain results through experience gained from records of successes and failures under known conditions.

Mr. Chamberlain: It will be no more than fair to give some of the people who are interested in the tar binder an opportunity

to say something. We have heard a good deal about the asphaltic macadam, asphaltic concrete, and Mr. White has mentioned the use of tar.

We have with us this evening Mr. C. G. Wells, of the Barrett Manufacturing Company. We should be glad to hear from him in regard to tar as a binder for macadam pavements.

C. G. Wells: There are three points on which I would like to speak,—the maintenance of light-traffic roads with Tarvia, a new specification for the penetration method, and modern methods of applying binders.

In many towns there are several miles—eight, ten or twelve—of macadam roads in good condition but rapidly going to pieces. These are the roads that Mr. White says have been laid in the last few years before the advent of the modern pavement. These towns have not much money in their street funds; they have to be economical, and the problem is, what to do to keep these roads from going to pieces. Oil has been tried, but in nearly every case, where the crude-oil applications—both the lighter and heavier grades—have been used, it has been found that the maintenance cost on these roads, instead of going down, went up very rapidly, and the engineers are looking for a material which, besides laying the dust, will act as a binder on the wearing surface.

There is on the market a grade of Tarvia (Tarvia B) which can be spread cold. This is a coal-tar preparation, flowing freely through the holes of a street sprinkler, which is applied to a well-bonded macadam surface, the amount put on depending upon the porosity of the road; in other words, the road is soaked with all the material that it will take. The road is then allowed to stand for a period of twenty-four hours without traffic and lightly sanded; inside of twenty-four hours after that it becomes a hard, smooth, asphaltic-like surface, and, furthermore, the material penetrates and forms a bituminous macadam surface anywhere from ¾ to 1 in. thick. The amount of material required is somewhere between 0.4 and 0.5 gal. per sq. yd. on the ordinary well-packed macadam road. The cost of this work varies considerably, but 4c per sq. yd. can be taken as the average cost for the work complete, with the exception of the sweeping of the road, which depends entirely on the methods used. A road so treated can be maintained over a period of years at less expense, if the depreciation or maintenance cost is figured in, than any application on the market, because in bonding and forming a bituminous macadam surface with this material, by the penetration method, it is the same as when the material is mixed in the mixer and spread upon a road; i. e., the stones are held in place against the wearing action of the traffic upon the road.

The second point is in regard to a new type of penetration construction with prepared coal tar—Tarvia. This is a construc-

tion which is used considerably in and around Boston and through Canada. It is what is known as a modification of the Gladwell system, which is extensively used in England.

The method of construction, which is applicable either to new work or resurfacing, consists in spreading upon a well compacted base about ¾ in. of rough sand. This sand is treated with a light grade of Tarvia, preferably spread under pressure, using about ¾ gal. to the yard. This soaks through the sand. Upon that is spread about 3 in. of broken stone grading from 3 to 1 in. in size, which is rolled down to a finished depth of 2½ in. That is to say, the distance from the base to the top of the finished pavement is 2½ in.; or, another way of looking at it, the stone is rolled into this tarred sand. The upper stones are then coated with 1½ gal. per sq. yd. of heavy Tarvia X; the smaller stones are then rolled in, the road is coated with ½ gal. of Tarvia A, and the screenings put on to finish. In other words, the stone has been bonded from the bottom up and from the top down.

The objection of many engineers to the penetration method is that they cannot secure an absolute guarantee of bonding from the top. The tar sand mastic overcomes that and makes the road a solid mass. An example of this construction is on Massachusetts avenue in Cambridge—a heavy traffic street; after a year and a half of service it seemed as good as an adjoining piece of bituminous macadam construction by the mixing method. In fact, one could not tell the diffeernce.

The third point is in regard to the use of machinery in the application of various binders, especially Tarvia, in the penetration method. The old method was the application of the material by gravity. In the *Proceedings of the American Society of Civil Engineers,* for March, 1912, page 327, is a full discussion on this subject. The consensus of opinion seems to have been that pressure is absolutely necessary for a good application of any binder, whether asphalt or tar. In the method used by the company which I represent, the tar is heated in a tank car, drawn into a closed container, and hauled hot to the job. This container holds about 500 gal. At the lower end is a 3 in. opening, which connects with a 2 in. hose, and at the end of the hose is an atomizing nozzle. On top of the tank is a ¾ in. pipe, attached by a valve to a steam hose, which connects with the steam roller. The steam is admitted and controlled by the valve at a pressure of from 15 to 20 lb. per sq. in. on top of the hot Tarvia, and the material is blown directly out through the atomizing nozzle on to the road. Delivering the tar in that fine spray, one is able to coat satisfactorily the top, the sides, and the under sides of stones; some parts of the tar going in under pressure, it rebounds and coats the under side of the stones, which is not accomplished to any great extent by the hand pouring. This method is specially advantageous to contractors on account of re-

ductions in cost. The cost of heating and spreading any binder by hand runs from 4 to 8c per sq. yd. The contractor by using a pressure spray can reduce that cost to 1c to 2c per sq. yd., which makes the proposition from the contractor's standpoint extremely interesting.

Edwin Hancock, M. W. S. E.: I would like to ask Mr. Schrader if the cost he mentioned of 61½c was for a two-course pavement.

Mr. Schrader: That cost was for a single-course pavement.

Mr. Chamberlain: One thing occurred to me while Mr. Kirschbraun was talking about tempering asphalts or fluxing asphalts. I would like to have Mr. Kirschbraun tell us what fluxing oil was used. I think different fluxing oils are used, that is, different consistencies in the oils.

Mr Kirschbraun: The fluxing oils ordinarily used for fluxing solid asphalts are liquids resulting from distillation of various petroleum oils. There is really no established dividing line between liquid reduced petroleum oil and semi-solid reduced petroleum oil. They shade, one into the other. But specifications usually adopt some arbitrary standard by hardness or consistency whereby a certain degree of softness will indicate flux and a certain hardness will indicate semi-solid treatment.

Mr. Chamberlain: It is not considered good practice, then, as I understand it, to use a light petroleum?

Mr. Kirschbraun: A heavy residuum oil should be used. The oils are of varying degrees of heaviness. They are all heavy, but some of them are more so than others.

Mr. Chamberlain: As I understand it, there is no definite line as to the specific gravity of the oil, and that is simply fixed arbitrarily by the man who is making the specification or according to his experience in tempering.

Mr. Kirschbraun: The specific gravity is fixed according to one's best experience for the different kinds of oils, or different kinds of fluxes; various asphalts require different kinds of fluxes to satisfactorily unite into cements.

Julius G. Gabelman, M. W. S. E.: One of the things I would like to have brought out is how these different pavements can be laid without infringing on the Bitulithic patent. The Board of Local Improvements of this city is revising all its specifications, and those on asphaltic concrete will be completed soon. There are specifications for asphaltic macadam, which include about thirty varieties or combinations. For instance, the base might be concrete and the surface macadam. Limestone, gravel, or granite might be used for the mineral aggregate in the wearing course, or else a high or low grade asphaltic cement.

The specifications will not allow the use of tar in any of the bituminous macadam. It seems to me that high grade asphalts would be more necessary on poured work than on machine-mixed

work on account of its greater adhesiveness. Also that with a machine mix the difference would not be so great.

In the specifications for sheet asphalt, Gilsonite has been eliminated except in combinations of equal parts with other asphalts. We do not allow the use of greater than 50% of that in combination with another native asphalt.

A point not brought out in Mr. White's paper was suggested by Mr. Wells' talk, and that is the top dressing with limestone screenings and even, I might say, granite chips. It seems to me torpedo sand would be a better and cheaper dressing than either of the other two.

Mr. Chamberlain: I would say to Mr. Gabelman that doubtless he knows that the Board of Local Improvements has been trying to dodge the issue by getting the contractor to assume the responsibility for the pavement, in connection with a number of specifications. The President of the Board sent out letters to the contractors asking if they would assume the damage suits that might result from laying bituminous concrete pavements or bitulithic macadam pavements—whatever they may be called—under the specifications of the City of Chicago. I do not know what most of the contractors told them, but I think many of them advised the Board that the City of Chicago would have to be responsible for its own specifications.

Possibly Mr. White, in his closure, can answer Mr. Gabelman's question in regard to the use of limestone chips or screenings and the use of torpedo sand as a top dressing. I can say from my own experience (I do not want to be prejudiced, but from my own experience, and I have tried them both) that limestone,—not screenings but limestone chips, what we call quarter-inch stone—has been the most satisfactory material that I have used, and I have worked under specifications where torpedo sand was used on top. I am not prepared to state positively what the wearing quality would be, but suppose that torpedo sand would give greater wear. Of course, we all know it is a harder material.

Paul E. Green, M. W. S. E.: I notice that Mr. Wells is somewhat alone in his appreciation of tar. My own position in this matter is that there is a place for tar,—a very decided place,—and also a place for asphalt, and that there is a place where both are sadly lacking. In the cheaper class of pavements, or rather the class of pavements which have a moderate traffic to take care of, I think the tar can be used very well. It has been suggested that tar be used as the main binder and a paint coat be made of asphalt. I see no reason why it should not be good practice, as tar is a better binder than asphalt; that is, it is inherently more "sticky," though not so stable. I wrote to the U. S. Bureau of Roads last summer about that point. They replied that the Government was going to experiment along that line this year, and that they could see no

reason why it would not be satisfactory. The combination has been used in Rhode Island, with apparently satisfactory results.

One very important point it seems to me should be given consideration. The mere stating that asphalt is the best for resurfacing, or that tar is the best for resurfacing, is not sufficient. The whole determination, it seems to me, rests on the traffic. I had an opportunity this past summer to make some observations on what traffic will do to macadam on Sheridan Road between the city and Lake Forest. We took a census for a week on the road at four different points, and also, of course, observed the condition of the road at the same time. One of the points is in Evanston where the Ridge Road meets Sheridan Road,—probably the point of greatest traffic on the road. The next one was at the line where Glencoe and Winnetka join; the third in Highland Park near the Moraine Hotel, and the fourth in Lake Forest. The maximum traffic was in Evanston, where it amounted to 2,500 vehicles per day; that is, between 7 A. M. and 12:30 at night, which covers the period the census was taken. The average was 1,200 vehicles. The census was taken during a week in which the temperature was rather below the normal. At the Glencoe-Winnetka line the maximum was 1,500; the average about 700. In Highland Park the maximum was about 1,200; the average about 700. In Lake Forest the maximum only ran up to 350, and the average about 220.

The result of those various amounts of traffic on the road was very noticeable. In Evanston the road was exceedingly badly worn, showing large holes, and at the same time it was being constantly repaired. In Glencoe and Winnetka there was very considerable wear, and the surface was much cut up. The roads had been heavily oiled and held quite well. In Highland Park the condition was about the same. Then, going through the reservation there is a long stretch of plain macadam. The traffic through this amounted probably to 300 vehicles per day; the surface was badly worn but not in exceedingly bad condition; that is, it was quite rough and ravelled, but there were no large holes. In other words, the balancing point was being approached. It is my belief, from this observation, that up to, say, 150 vehicles per day, of which probably 75% are automobiles, the macadam will do very well, if it is maintained as any macadam should be maintained.

Another point that ought to be considered is the roadway width. Where the traffic is very heavy, I think it is a great mistake to put down such a pavement as that which is called bituminous concrete. I believe that for streets such as Jackson street in Chicago, it does not have any place. The roadway is narrow,—about 38 or 40 ft.,—and the traffic as determined by the South Park Commissioners, is about 25,000 vehicles per day. The result of such an amount can already be seen on the new pavement on Jackson street at this time. It is less than a year old, but is stripping badly. Probably in an-

other year the repairs will be very heavy. That is to be expected. There was a sheet-asphalt pavement there before, and the maintenance was undoubtedly very heavy. It is my belief that as far as stability is concerned, none of the newer bituminous concrete is the equal of the standard sheet-asphalt.

Another place where this might be noticed is on Michigan avenue, where there was an exceedingly good asphalt pavement in the vicinity of Twenty-first street. My impression is that the pavement is about six years old, and until this last year it was a beautiful example of a perfect asphalt pavement. But during this past hot summer it began to rut very heavily. The traffic there is exceedingly heavy, and the roadway is only 50 ft. or thereabouts. I think the mere fact that the roadway is so narrow, with that enormous traffic, shows that the pavement is not fitted for that width of roadway. Further north, where the roadway is 75 ft., is a bituminous concrete pavement which, while it has not rutted, is cracking badly. That is, I think it is due to either foundation trouble or is the result of the use of blown-oil asphaltic cements. Further north, however, where the binder course described by the author is under the mixed surface pavement, there is no cracking, although the pavement is badly worn.

Mr. Chamberlain: Mr. Green brought up a point which has not been touched on before, and which I think is a very important one, because the width of the roadway very materially affects the wear of any macadam street. Numerous cases have come under my observation where complaints have been made of narrow driveways which are wearing badly, very often private driveways where there is room for only one vehicle, and not room for two vehicles to pass. It is almost impossible to keep a driveway of that kind in good condition, although the traffic is light, for the simple reason that a great majority of the vehicles that come in are one horse vehicles and there is no rolling of wheels in the center of the driveway and there is a pick-up of horses' roofs. We have found in a great many cases where complaints have been made that macadam drives did not wear properly, it was due almost entirely to the fact that it is almost an impossibility to keep a single roadway drive, where there is just room or a little more than room for a single vehicle, in any proper condition, no matter what type of pavement is put down.

Closure.

Linn White: Referring to the question of top dressing, raised by Mr. Gabelman. Going back over some of our experience, not with the machine-mixed bituminous concrete, but with the penetration or poured work, in which the top coat and top dressing is quite similar, the earlier work we did was covered with limestone screenings. A very large portion of the screenings was dust; the result was that little of the coarser material was forced into the top dressing, and it was quickly lost. It amounted to but very little.

The first improvement was made in abandoning the dusty screenings and taking clean limestone chips. That seemed to be a good top dressing, especially where traffic is comparatively limited, but it powders rapidly. It is only a question of months or possibly a year before it grinds up and all appearance of limestone is gone, it being completely forced into the surface or else worn away. Granite chips seemed to be an improvement on the limestone because they did not grind up so rapidly, and in our work we thought, when first used, that granite chips about ½ to ⅝ in. in size made an ideal surface. They have proved so where the traffic is largely automobile, and where it is especially desirable to keep a grainy, gritty surface to avoid the danger of slipping. But wherever horse and iron-tire traffic comes on the granite chips, it is only a matter of time as to how soon they grind up. From some things I have observed, I believe they may be injurious to the pavement, because, in breaking up, the granite forms hard, sharp particles which help to cut away and start surface wear. I think this effect has been noticed very clearly on two downtown pavements where traffic is quite heavy. On Jackson street and Michigan avenue north of Jackson street the grinding up of the granite surface has undoubtedly been injurious to the pavement. In such cases I believe torpedo sand is the better type of dressing, if it is kept as free as possible from dust.

As to Mr. Gabelman's question about the Bitulithic patents, that is a deep subject and one that is hard to give a conclusive answer to. Some of the things mentioned in the paper were intended to give the best answer I know to this question. Avoid the grading that is called for in the bitulithic patents, avoid the predominance of the larger grades of stone, using a finer mixture; and where you may lose "inherent" stability by these changes you will get it back in a greater degree by using a coarse, open binder course. I believe that in this way with care, a pavement can be made equally as good as though coarse stone were used with the mixture, and I am firmly of the belief that there is no patent—bitulithic or any other—that would control the making of a pavement of this sort.

The general question of tar versus asphalt is one that possibly will never be settled. I think there is no doubt but that most excellent pavements have been made out of both. The tar has its place and will continue to be used. I think for the sort of work Mr. Wells mentioned, particularly the maintenance of existing macadam roads where the question of expense is important and where traffic is not very heavy, there is nothing better than tar, and where handled with discretion excellent pavements can be made of it.

I alluded to a piece of paving in Jackson Park, of penetration work that was done in 1908, I think. I do not know of any pavement surface in the country that is more pleasing and answers the purpose better; but if that pavement were on some or our streets

where there is horse traffic and iron-tire traffic, I am satisfied that it would go to pieces in a short time.

On Michigan avenue along about Twenty-first street, where the marks of wheels were so noticeable last summer, there is a sheet-asphalt pavement which has been in use about eight years. It is a Trinidad pavement, and until this year it never gave any indication of weakness, but during the summer ruts were formed, part of which were cut out and replaced. On other portions of Michigan avenue the bitulithic pavement, as almost everyone knows who traveled out that way last summer, was very badly rutted. In both cases I think the trouble was due to the fact that the pavement was too soft. In the case of the sheet-asphalt, it was perhaps under a higher and longer-continued high temperature than it had been during the eight years of its life, and the greatly increased automobile traffic brought a heavier strain on it than it had ever had before. I think there are pavements in some other portions of the city, particularly on West Jackson Boulevard, where during the summer there appeared some of the same indications,—a pavement that had stood well many years. The blown-oil asphalts used in the South Park system, on account of their lack of susceptibility to changes of temperature, withstood the hot weather and stress of traffic most excellently, but their principal weakness comes, of course, during cold, damp weather.

So, as I said in my paper, if we can find a bituminous binder that has the merits of the two, I think we shall then have the ideal binder or cement for paving surfaces.

The amount of heavy traffic on Jackson street and on Michigan avenue north of say, Adams street, is unquestionably too great for any bituminous pavement, certainly anything that is constructed with the idea of economy. If it were possible to make a very lasting bituminous pavement of any kind,—sheet asphalt, asphaltic concrete, or anything else,—on those two streets, it would surprise me. The last three years the Bermudez sheet-asphalt pavement was in use on Jackson street it cost from 15c to 25c per sq. yd. for maintenance. I do not know that the asphaltic-concrete pavement which is on there at preesnt will give any better account of itself. Traffic conditions are growing worse every year. Records taken on portions of Jackson street show between 6,000 and 7,000 vehicles during the twenty-four hours, 75% of which are heavy loaded teams. On Michigan avenue north of Jackson street the records have shown as high as 17,000 vehicles during the twenty-four hours, of which about 4,000 were two or three horse teams, scarcely any of which were loaded under three tons,—many from three to seven tons. It is true it is a wide street, but teaming traffic does not distribute itself very much. It generally falls in line and follows the line as long as it remains on the street.

NEW DEVELOPMENTS IN STEAM TURBINE ENGINEERING

Edwin D. Dreyfus.*

Presented March 4, 1912.

The first milestone of turbine progress was reached when Parsons introduced his unique turbine in 1884, which time witnessed the transition of the steam turbine from the realm of virtual mysticism—as these motors in their primitive form probably impressed the people of the earlier days—into apparatus of commercial utility.

Its advance was naturally slow during the early period of development, but it gained notable headway in the ten or fifteen years following its introduction. The most prominent factor in preventing a more general use of the turbine was the lack of machinery which could utilize, in a practical way, the power developed. The turbine being inherently high speed, made the provision of a driven machine of corresponding speed necessary, or else connection through reducing gears, and inasmuch as these were not available in the infancy of the industry, turbine progress has therefore in the past been more or less closely related with the complementary electrical equipment,—chiefly of the alternating current type.

The first generator which was driven by a turbine was of the historic bipolar "Jumbo" design, operating at a normal speed of 18,000 r. p. m. and developing a maximum output of 6 electrical h. p. From this modest beginning the turbine was energetically pushed, and by 1889 turbine units aggregating 5,000 kw. were installed and operated, and in 1894 the 10,000 kw. mark had been reached. This period not only witnessed the initial application of the turbine to marine work, but also marked a beginning of the broad highway of turbine progress leading down to the present day, which claims an aggregate turbine capacity of 25,000,000 h. p. in actual service.

The developments have been so far-reaching during the past few years that many new milestones have been rapidly passed. Thus, for instance, the range of turbine capacities has been extended from 1 to 20,000 kw. and above; the low pressure turbine, the automatic bleeder turbine, the improved non-condensing turbine have been accorded wide application in central station work. In auxiliary service such as excitation, boiler feeding, and condensing equipment, the small turbine is filling a long-felt need. The practical development of the reduction gear for high powers has brought the turbine into the high-duty water pumping field, and has provided for the

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application of large high-speed turbines to direct current generation, and likewise to non-reversing rolling-mill drive.

Thus it may be properly said that the turbine has invaded practically every class of power application, with the possible exception of those cases requiring reversing operation, as in hoisting and blooming mill-work.

As a review of turbine development, it may prove interesting to reproduce the following tabulation:

*Table 1.—Performance of Parsons' Turbo Generators at different epochs.

Date.	Power kw.	Steam per kw. hr.	Vacuum 30 in. bar.	Supht. Deg. F.	Steam Pres. lb. per sq. in.
1885	 4	200	0	0	60
1888	 75	50	0	0	100
1892	 100	27	27	50	100
1900	1,250	18.22	28.4	125	130
1902	3,000	14.74	27	235	138
1907-10	5,000	13.2	28.8	120	200

Hence it will be seen that the turbine came up to the best reciprocating engine performance in a comparatively short time, and today excels in all important sizes.

RANGES IN COMMERCIAL SIZES.

Probably one of the most notable features of turbine progress has been the remarkably short space of time in which its design has become feasible for both very small and very large powers. A few years ago the concentration of 50,000 h. p. in a single machine was not seriously thought of even by those who are customarily accredited as visionary. Although at the present moment we have no turbine which has as yet reached these stupendous proportions, we are, however, today observing the building of units of 30,000 h. p., and the next step to the large size named is now readily surmountable. One may fully grasp the significance of this advance when it is considered that a 30,000 h. p. unit will displace four of the largest reciprocating engines built, and, moreover, occupy but 25% of the space and volume. It is at once apparent that there is a large measure of economy realized both in investment and running expense. With increasing size of turbines there is a continual improvement in economy, all conditions being favorable. The most important factor in large turbines, then, is the question of mechanical design. There can be no doubt that a rigorous demand is made of the designer that the essential details be executed with every regard for operating loads and stresses. Several different types of large turbines are being brought to the fore, but the preeminent fitness of any will be properly gauged, of course, by their relative immunity from troubles of any moment. The drum-type turbine has much to recommend it, particularly for large powered units. A detail section of a turbine of this construction is presented in Fig.

*From A. Richardson, "The Evolution of the Parsons' Steam Turbine."

1, and which as proportioned is capable of developing 20,000 kw. or 30,000 h. p. This represents the double flow type, combining the impulse and reaction principles, and through the division of steam between the right and left hand elements, higher rotative speeds have been made possible with the reduction in diameter of the low-pressure rings. As a result, substantial betterment in construction, and a decrease in weight and dimensions, have been effected, ensuring greater homogeneity of the entire structure. It will be noted that the unit is constituted entirely of drum and blade rings. Discs are not employed. Operating at 1,500 r. p. m. may appear somewhat startling at first when some of the early designs of turbines adopted speeds of 750 r. p. m. for units of only 2,000 kw. capacity. Strange as it may seem, the disc construction, although it is capable of being worked at higher stresses than the drum type, the latter may be constructed with greater facility to comply with requirements of good steam economy and still possess the greater factor of

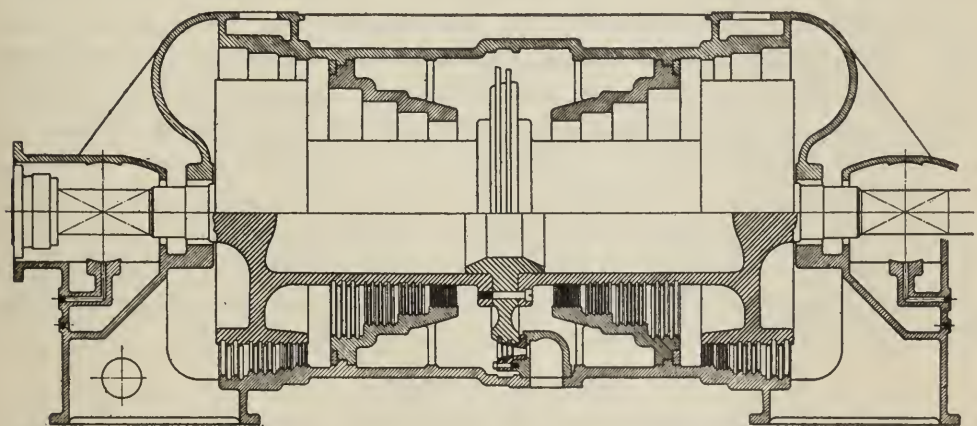


Fig. 1. Drum Type Turbine—Large Size.

safety. The steam consumption with moderate working condition (175 lb. gauge pres. 100 deg. supt. and 28-in. vac.) would at full load amount to 13.5 lb. per kw. hr.

When the very small turbines are considered, the problem is of a different order in obtaining maximum simplicity with reasonable efficiency. A sectional view of a turbine of 1 kw. capacity is shown in Fig. 21. It comprises merely a single wheel with one row of impulse blades. Double use of the velocity of the steam is effected through reversing chambers, which contributes toward higher efficiencies. Any practical requirement calling for even less power could be inexpensively provided for in a turbine of this type.*

Between such limits the variation in design is quite marked.

*This type is described in detail in the author's paper, "Steam Turbines for Electric Stations of Moderate Size," read before the Mississippi Electrical Association, 1911, and published in *Electric Journal*, September, 1911.

Single disc wheel construction is retained until capacities of 300 kw. are reached. At this point, the steam volume becomes sufficient for using reaction blading of economical proportions. There is manifestly a definite relation of the leakage annulus or area over the tips of the blades to the blade lengths, which prohibit their use commercially in smaller sizes. On the other hand, the percentage leakage loss greatly diminishes with increase of size, and the economy is correspondingly improved.

Consequently there exists a large variation in construction, depending upon both working conditions and capacities involved, and the designs therefore take either the form of a simple impulse wheel, or the straight Parsons construction, or else some effective combination of the two. For moderate sizes, somewhat above and below 1,000 kw. capacity, the straight Parsons type works out most advantageously in regard to economy and mechanical design. In larger sizes there is much gained from a structural standpoint by means of the combined type, although the efficiency is not noticeably affected. The condition is practically the reverse in small units, where the construction requirements cease to be a factor, while the efficiency may be improved by replacement of the very short blades in the high-pressure section of a Parsons turbine by an impulse wheel. As the character of the work varies, different arrangements may be adopted, and these facts simply serve to illustrate that the turbine is no longer circumscribed by narrow limits, but admits of wide flexibility in its application. Many of the features here described will be observed in the accompanying detail views of turbines built for various purposes.

SPECIAL SERVICE.

Under this classification, the implication is that special regard must be paid to the proportioning of the turbine with reference to the nature of the steam supply as well as its speed and the output developed. It is here considered that the complete expansion of the steam from boiler pressure to the absolute vacuum maintained represents ordinary practice, and would therefore only require the regular designs already referred to. But there are sets of conditions which call for special designs, briefly enumerated below, and which typify some of the more prominent of recent developments in the steam turbine art.

(1) Utilizing low steam pressures, atmospheric or less.*

(2) Operated strictly non-condensing, with or without back pressure.*

(3) Diverting part of the steam from the turbine for heating purposes, termed bleeding operation.

*Curiously, the first steam engine operated altogether on low-pressure steam (atmospheric condenser pressure), but evidently this was due to the state of the mechanical art at that time, and necessarily involved special conditions.

Low-pressure turbines have now become so well known that little mention of their advantages need be made here. It is possibly well, however, to reiterate the salient point that they profitably utilize the lowest practical exhaust pressures, where the reciprocating engine would receive no benefit, direct or indirect. One of the most convincing demonstrations of this quality of the turbine is the large number of stations which formerly operated non-condensing piston engines on account of inadequate cooling water supply, which are being converted into condensing plants through the addition of low-pressure turbines and cooling towers. The engines alone would not have justified the cooling-tower investment. Improvement is not only to be found in the existing non-condensing systems, but power plants formerly consisting of the most modern type of compound condensing reciprocators have been able to realize a large betterment in economy by supplementing the engines with low pressure turbines. A concrete example will forcibly attest the economic results attained. An electric railway power station originally contained five 1,000 kw. Corliss compound condensing engines. A low-pressure turbine of 2,500 kw. capacity was later installed. Concisely the improvement obtaining is:

(1) Plant capacity increased 50% ; additional boilers unnecessary.

(2) Reduction in station operating force 15%.

(3) Fuel saving 22%. The fuel is of 11,000 B. t. u. value, cost $1.40 per ton delivered, and is equivalent to a return of 48% on the investment, or, in other words, the new installation would pay for itself in two years' time.

Besides these items, there is economy effected in oil, supplies, and repairs. Moreover, this addition was made at (roughly) one-half the cost that would have been necessary to install duplicate engines. A type of low-pressure turbine which is extensively used, also embodies the double flow construction, and is quite similar to Fig. 1, with the high pressure part, however, removed. That part of low-pressure turbine engineering which attracts the greatest attention, is the variety of the systems of governing which have been developed to satisfactorily secure elasticity and efficiency over a wide range. These may be divided into, approximately, six classes, and which, as given on previous occasions,* are as follows:

(1) Without governor—electrically controlled through synchronizing force of generators.

(2) Governor control with auxiliary live steam admission.

(3) Electrical tie between turbine and belt engines through synchronous motor.

*Note paper read before the Indiana Electric Light Association, August 24, 1911, and for further discussion of the subject, see paper, "Various Phases of Low Pressure Turbine Work," *Electric Journal*, May, 1911.

(4) Automatic by-passing of surplus low-pressure steam to condenser.

(5) Use of a reserve high-pressure element.

(6) Heat regenerators, accumulators, and storage systems.

While heretofore the development of the low-pressure turbine has mainly centered about the governing mechanism, an important innovation in the mechanical design has been made in the construction of a convertible type as shown in Fig. 2. This is a single flow reaction element with provision for the introduction of a high-pressure impulse wheel when operating conditions may demand it. Such a type would prove of great value in the case of abundant exhaust steam being available at first, but afterwards seriously reduced by

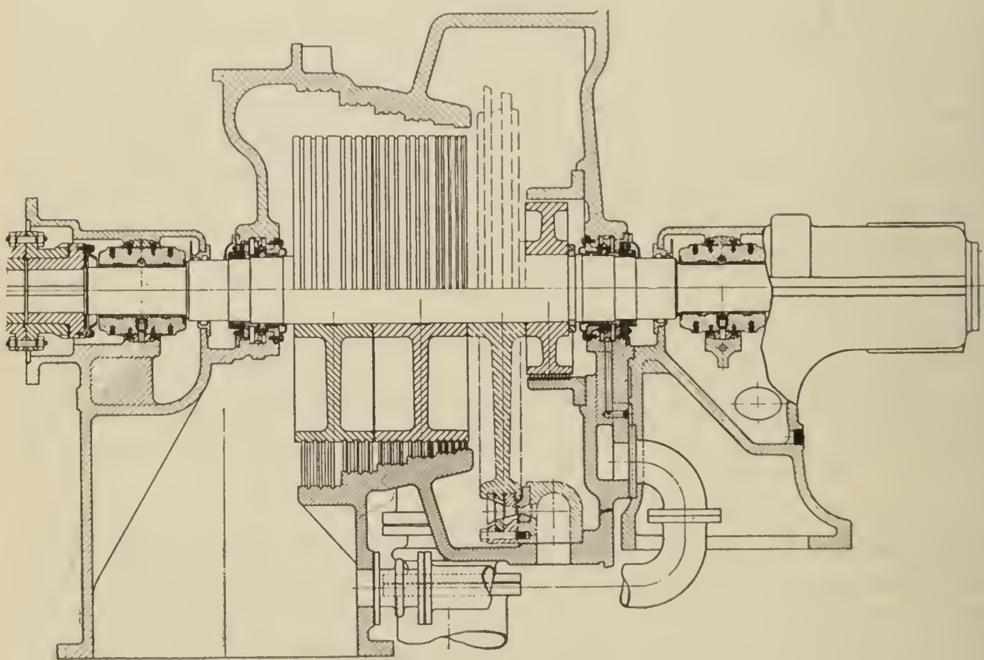


Fig. 2. Convertible Type Turbine.

other changes about the plant, full advantages of the low-pressure feature may be thereby lost. By locating a high-pressure wheel as shown, the turbine may be economically operated either as a mixed pressure or independent high-pressure unit.

Much has already been said of the facility with which low-pressure turbines may be adapted to widely different requirements. There is another feature in combining it with a given engine, worthy of special comment: viz., that of the low-pressure turbine to be selected being not necessarily confined to a fixed capacity. But, on the other hand, there is considerable latitude practicable in the selection of the low pressure turbine, thus making possible different overload capacities and light load economies without greatly affecting the efficiency of the combined unit at rated output.

With these advantages, the size of low-pressure turbine would then be influenced either entirely by present conditions or by future requirements as regards the combined normal capacity.

The points to be considered center primarily about the selection of the intermediate pressure between the engine and the turbine to carry normal capacity of the turbine. Obviously the higher this pressure is set, the smaller the low-pressure turbine frame for a given capacity. On the other hand, the lower the pressure taken for normal conditions, the larger the low-pressure turbine frame must be. Evidently in the first case of a high intermediate pressure, the output from the engine becomes materially reduced and maximum overloads which may be carried are likewise affected. This fact may be best appreciated from Fig. 3, showing the total water characteristic of the high-pressure engine when operated in connection with turbines of different sizes. As the back pressure on the engine is lowered, the turbine size must increase, which, in addition to extending the point of maximum economy of the engine, also raises the capacity of the combined unit. The range in operating load should also be considered, since, where larger turbines are operated at light loads, the economy may be inferior to that shown by the unit having the smaller low-pressure turbines. This is due to the fact that light-load losses, for fractional-load operation of the combined unit, are greater for the larger than for the smaller turbine.

By working out a definite case it has been found that where the turbine size is increased as above, the gain in the engine due to lowering the back pressure, slightly exceeds the loss in the turbine element following upon a decreased inlet pressure and fractional-load operation. This is evident from Fig. 3, showing results that have been deliberately worked up for a 28 and 54 by 48 in. engine, operating with low-pressure turbines ranging from 500 to 2,000 kw. capacity.

For a definite quantity of steam passed by the high-pressure engine, the output of the latter, as determined by the resultant total water line when combined with a turbine of the capacity under investigation, is simply added to that developed by the turbine. In obtaining the latter from the total water lines, due allowance must be made for moisture in the engine exhaust and for the pressure drop between engine and turbine usually taken at from 1 to 2 lb.

The combined output thus developed is compared with the total steam passed by the high-pressure unit, determining the combined economy curves on the right, Fig. 3.

As will be observed, the effect of turbine size upon overall economy is, within certain limits, negligible, and may, therefore, be ignored where other conditions favor the choice of a particular turbine capacity. The reason for this close agreement in efficiency is quite plain. Assuming an engine of given size, there is obviously

one turbine capacity that will give the best overall results. Variation either way from this best turbine size will cause the engine performance to either improve or decline, as the case may be, the turbine economy being affected in the opposite direction. Thus, for

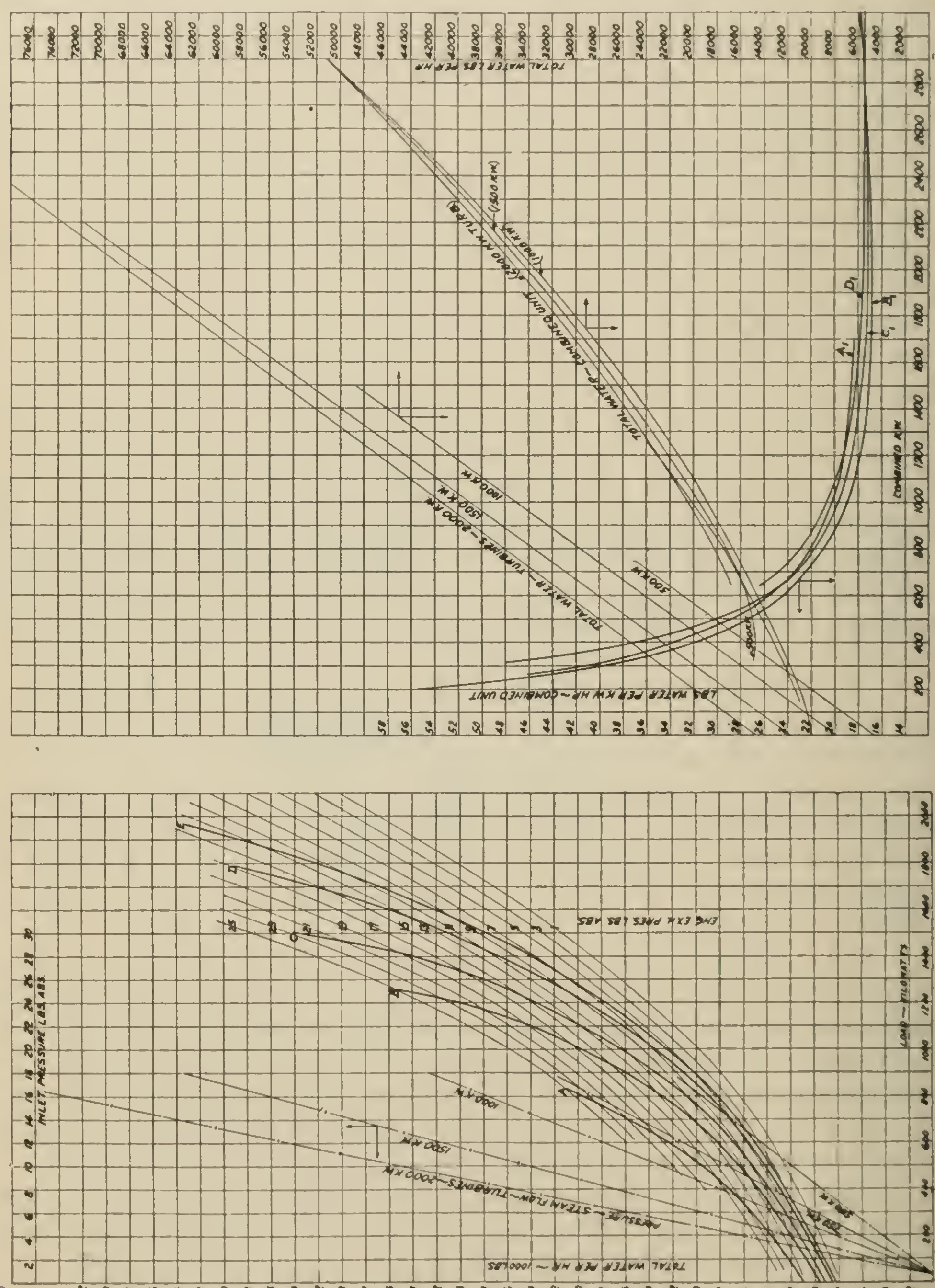


Fig. 3. Curves Showing Steam Economy.

a given departure from the best turbine capacity, the improvement in one element offsets the decline in performance of the other, maintaining the net results virtually constant within a fixed range.

LARGE NON-CONDENSING TURBINES.

These turbines have not hitherto been regarded as competitive to the non-condensing Corliss compound engine since the high-pressure piston engines have performed very efficiently. Improvements in the design of the turbine for non-condensing work, have, for all practical purposes, overcome the advantage previously possessed by the steam engine. In brief, these results have been accomplished by increased speed ratings and better steam distribution. Tests made three years ago on a 600 kw. non-condensing turbine (obviously of the earlier design), proved the disparity between its performance and that of a first class Corliss compound non-condensing engine to be less than 5%. Later modifications have virtually placed the steam consumption of the large non-condensing turbine on a parity with the engine; and with oil, supplies, maintenance and investment in its favor, the large non-condensing turbine should logically be preferred to the reciprocating engine. Reduction of internal windage losses is imperative in the non-condensing turbine if good efficiencies are to be realized. The drum construction is known to suffer much less loss than the disc type, and is therefore superior. Paradoxical as it may appear, the high-pressure section, which is the most inefficient section of the complete expansion turbine, becomes quite satisfactory in the non-condensing unit. The explanation is simple, inasmuch as the quantity of steam flowing is doubled (with the available energy being halved), so that the ratio of leakage area or annulus to blade height, is very much more favorable to economy.

The advanced construction of large non-condensing turbines is shown in detail in Fig. 4, incorporating many interesting improvements in working parts. The smaller non-condensing turbines are not capable of making quite so favorable a showing on the basis of heat efficiency, but, as is now well understood, the steam economy in small operations is not so vital a factor as in the case of large prime movers.

The sustained efficiency of the turbine, as compared with the vagaries of the engine, needs no emphasis, and it is probable that any lead the small engine may possess initially, will disappear unless the engine is constantly governed and cared for, which is the exception and not the rule. Fig. 5 shows the photograph of the spindle of a 1,000 kw. turbine.

In regard to special applications of the steam end, the design of the automatic bleeder turbine is undoubtedly the most unique of recent developments. It is arranged to profitably serve a combination of independently varying light and heat loads which may be supplied from a single station. Previously the turbine was at a disadvantage under these conditions, where spasmodic stage bleeding was resorted to. The readiness with which the turbine is adapted to the automatic bleeding operation will be appreciated

from Fig. 6, showing a section through such a turbine. The departure from standard construction consists in the main of locating a diaphragm *A* between the intermediate and low-pressure stages, the flow of steam being regulated by a gravity controlled valve *B*. Live steam is admitted at *C*, and on passing through the high pressure and intermediate sections, part is diverted to the heat-

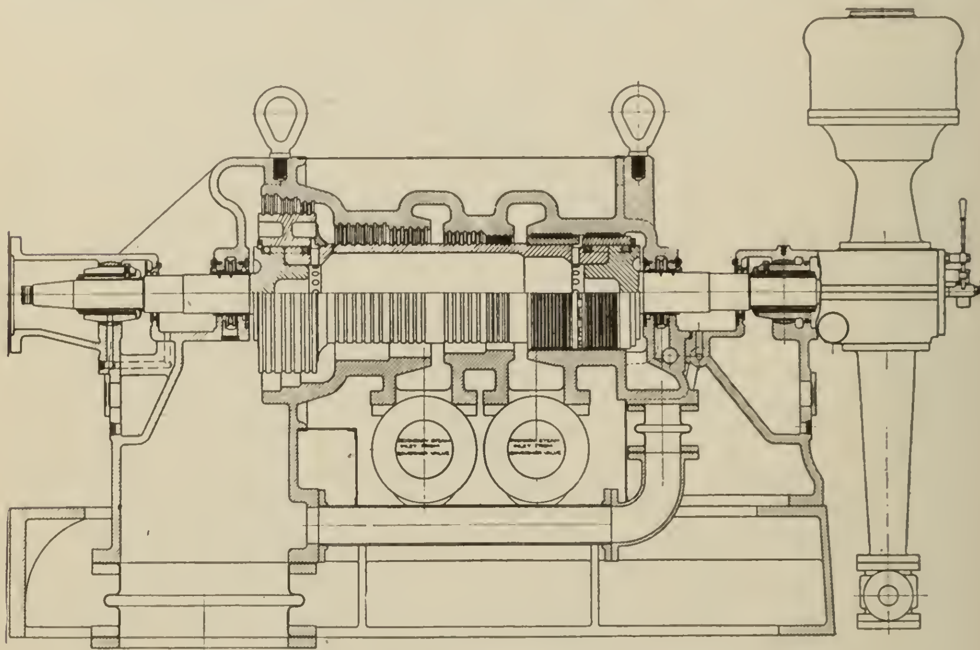


Fig. 4. Non-condensing Turbine.

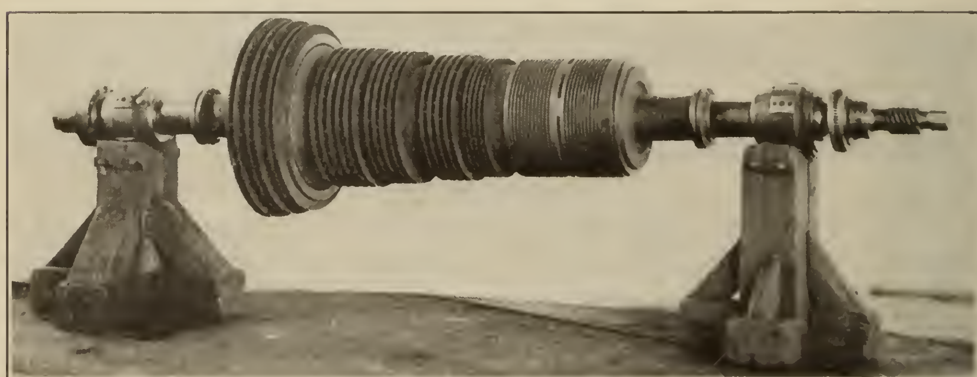


Fig. 5. Spindle of 1,000 Kw. Turbine.

ing system through connection *H*, the surplus passes through the low-pressure section to the condenser. It will be seen that when the pressure in the heating system rises above any predetermined amount as would occur with a decreased heating load (according to the auxiliary or counterbalancing weight used), the valve *B* will be elevated and more of the steam will continue through the

low pressure section of the turbine, developing there an additional amount of work.

There are many manufacturing establishments, and likewise central power plants, where a joint demand for heat (from low-pressure steam) and light occurs. With the growing tendency to economically proportion the plant layout, and with provision for automatic regulation for all variations kept in view, the value of this design will at once be appreciated. Such an installation is shown in Fig. 7. Presumably the importance attached to this design will become plainer when we examine the characteristics of the bleeder type. In addition to the economy and the elasticity of application, a wide range in the selection of not only the unit itself, but also of its complementary condenser, is readily seen. To facilitate a proper grasp of its economic possibilities, the triangular

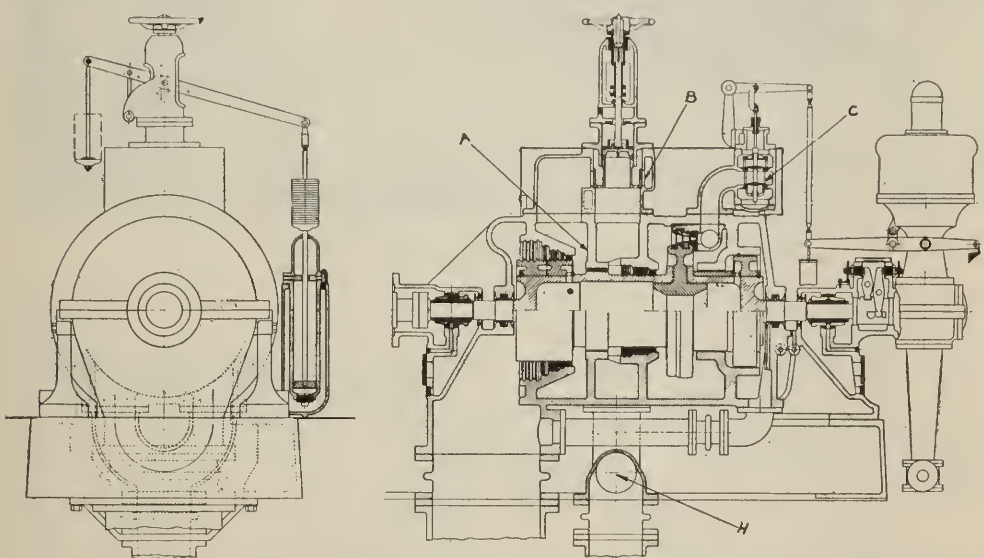


Fig. 6. Automatic Bleeder Turbine.

chart, Fig. 8, has been developed, enabling a ready appreciation of the relation between the steam bled, the steam supply to turbine (otherwise, draft on the boilers), and the quantity passed to the condenser for a given power load sustained by the unit. These curves have been plotted against brake horse power on the horizontal, and weight of steam bled on the vertical scale. The solid lines extending up and to the left are lines of constant steam supply and show the increase of available power with decreased bleeding. As will be observed, this is a straight-line relation within certain ranges, the power output increasing at a constant rate as the amount bled decreases, or, what is the same thing, as the amount passing through the low-pressure stages increases, shown by the dotted lines extending up to the right. It will be noted that as the latter reaches a certain value, i e., about 21,500 lb., the slope of

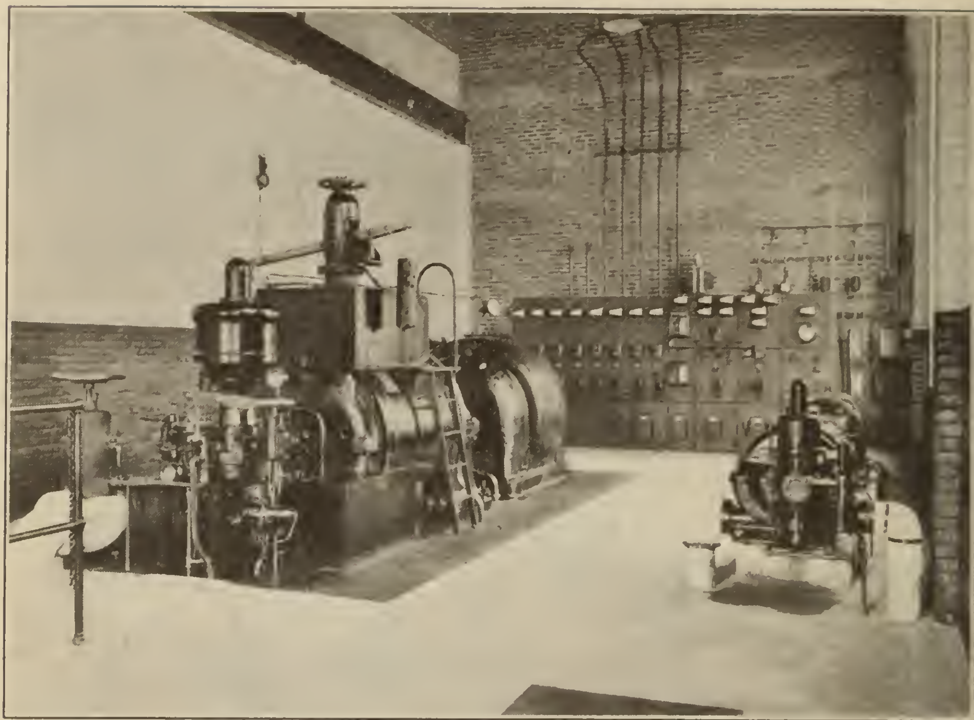


Fig. 7. Electric Light Plant, with Steam Turbine.

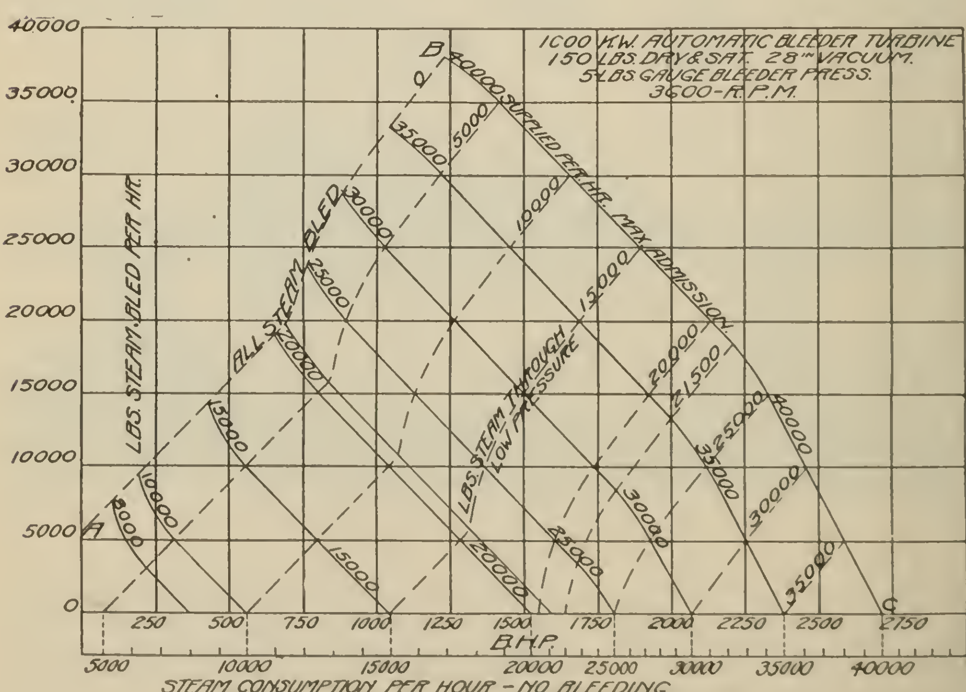


Fig. 8. Chart Developed to Show Economic Possibilities.

both the dotted and solid lines becomes steeper, and correspondingly the rate of increase of power output is appreciably diminished. This is due to the opening of the secondary overload valve, as the bleeder turbine is designed for a normal bleeding demand, and the low-pressure stages are accordingly proportioned to pass a certain quantity of steam. Therefore, when this is exceeded, the turbine output, while still increasing, does not do so at so fast a rate.

To complete the explanation, a supplementary scale, Fig. 8, has been added below that of the brake horse power, which gives at a glance the total steam consumption of the unit operated strictly condensing (a limiting condition). The other two interesting limits are lines *AB* and *BC*. The line *AB* gives total steam with no work developed in the low-pressure cylinder; i e., all steam bled at the particular load, and *AB* establishes the boundary for maximum power which may be developed when a predetermined amount of steam is bled. It should be noted that when all steam is bled, as shown by the limiting line *AB,* there is a small difference between the total amount supplied and that accounted for by the quantity bled. On first thought it would seem that these should be equal, but owing to the construction employed, a small portion of the steam leaks past the packing into the low-pressure section, which explains the apparent discrepancy.

A careful study of the chart will furnish a broader view of bleeder turbine characteristics and will considerably assist in the choice of the condenser capacity best suited to the particular set of conditions. In the non-automatic bleeder, the performance could not be so clearly demonstrated as the bleeding is not so closely related to the internal operation of the turbine. This chart obviously applies only to the capacity noted and for the conditions set forth. Evidently a change takes place for any variation in size or nature of operation.

Similar conditions are undoubtedly bound to arise in large undertakings, and the point in question will manifestly be the feasibility of providing large turbines for the purpose. This consideration has already been given due thought, with the result that plans have been prepared for accommodating large turbines to the work, and a diagrammatic illustration of the double-flow construction accordingly arranged, as shown in Fig. 9. These simple illustrations serve to show how fortunately the steam turbine has lent itself to the march of the world's progress.

APPLICATION TO POWER HOUSE AUXILIARIES.

In the development of the turbine, attention was first paid to the building of main units where it was perceived that the reciprocating engine had its limitations. Evidently almost as many factors commend the turbine for auxiliary drive as for the large prime mover. They are, in brief, uniform rotation, absence of vibration and shock, *elimination of oil in the exhaust,* reduced floor space,

and decreased maintenance and investment charges. Consequently turbines are now being successfully used to drive:

(1) Exciter sets.
(2) Condenser air and circulating or evacuating pumps.
(3) Centrifugal boiler feed pumps.
(4) Blowers for mechanical draft.

DIRECT CURRENT TURBINE GENERATOR SETS FOR EXCITATION PURPOSES.

These sets naturally followed in the wake of the large alternator, in spite of the fact that the first turbine unit generated direct current. The commutator problem was the most difficult to overcome in direct current work, and therefore this type has proceeded slowly. While this feature has been completely solved in all small sizes, the use of the large direct-coupled generating unit is still

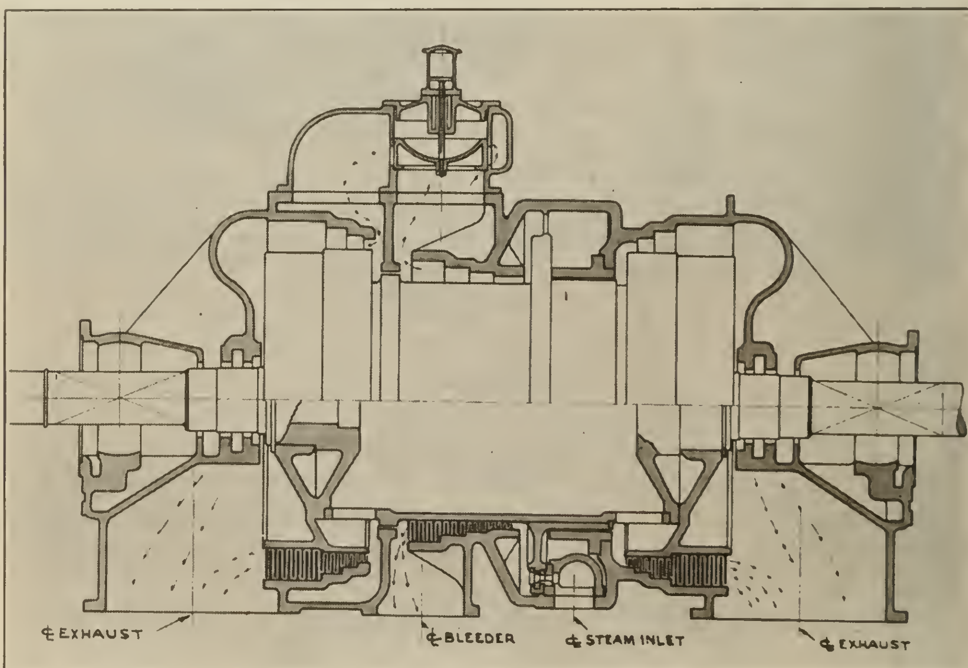


Fig. 9. Double-Flow Type of Turbine.

open to debate. There are various types of small turbines, but they are in practically every case of the impulse class, since the reaction type does not lend itself commercially for small powers. Simplicity being the byword in the design of small turbines, the axial reëntry principle has many merits, the main feature being that a single-bladed wheel only is required, multiple pressure and velocity drop being attained through reëntry nozzles and passages. This construction has been in general use for some time, and hence is familiar to power-plant operators.

In this arrangement, relative changes in the parts for varying operating conditions is carried out in a most simple manner, either by increasing or decreasing the nozzle and reversing cham-

ber areas and angles according to requirements, one set of castings thus being applicable to a wide variation. This is extremely important in small sizes on account of the greater possible range of working pressures, and such characteristics as noted are necessary in order that they may be properly taken care of. The nozzle block and reversing chambers in Fig. 10 (a detail of a 50 kw. exciter set) exhibit the reëntry principle.

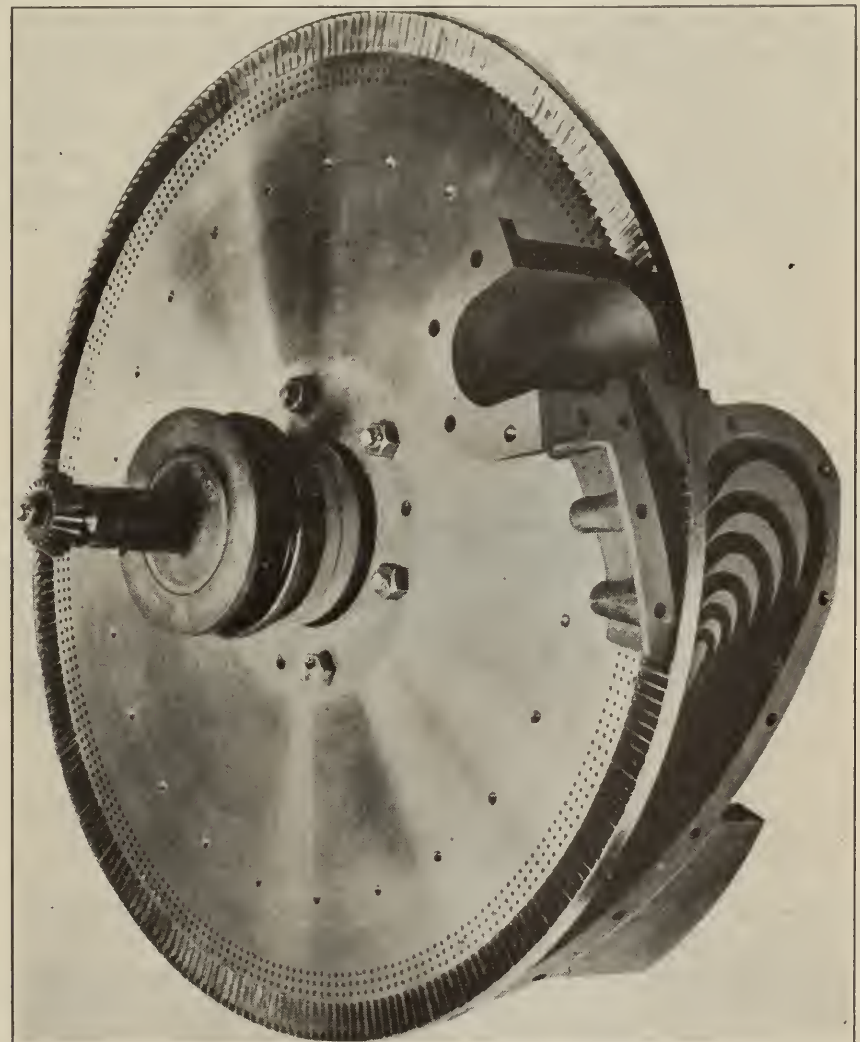


Fig. 10. Turbine with Nozzle Block and Reversing Chamber.

Although *centrifugal pumps* have been used since about 1880, or possibly a little earlier, for working against high heads, they have come into vogue in the *boiler plant* only within the last five years. Centrifugal boiler feeders might be conveniently operated by electric motors, but the usual demand for exhaust steam for feed water heating requires that they be steam driven, hence the direct-coupled turbine unit. Owing to the relation of capacity, pressure,

and impeller diameter, the centrifugal pump is not suited to small capacities and high head, and this design may therefore be employed only in plants exceeding 2,500 h. p. Ordinarily a stage is provided to create 50 to 70 lb. pressure. Consequently for in the neighborhood of 175 lb. gauge pressure, a three-stage unit is required. A sectional exhibit of a three-stage pump and the driving turbine is shown in Fig. 11, which displays fundamental simplicity in contrast with the multi-deck valve plunger pump. Difficulty with valve packing and of close governing has been obviated in this type. There is no definite way of comparing efficiencies, but it is reasonable to assert that where the centrifugal pump is operated beyond two-thirds of its rated load, it should excel in efficiency. Actual experience with the two types of boiler feeders should be a criterion by which to correctly judge them. One operator who installed this type of apparatus in 1906, has expended practically

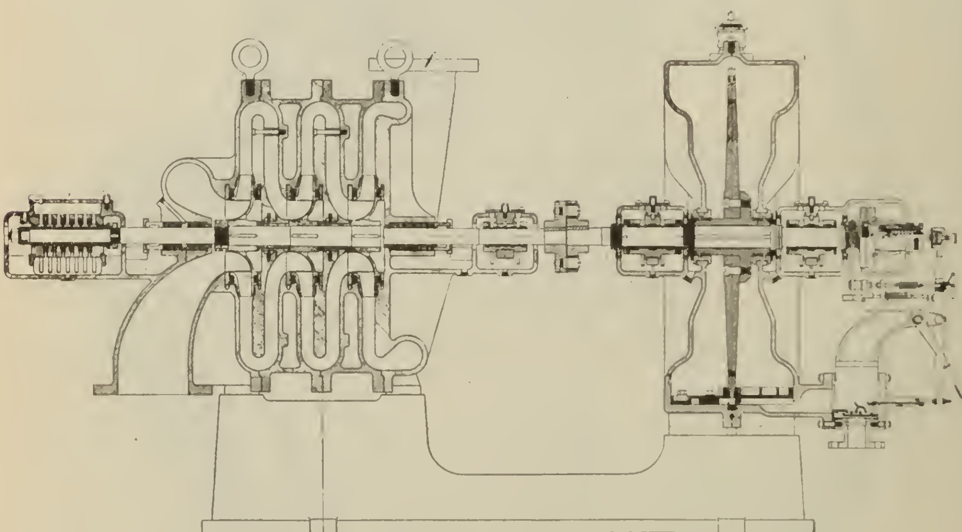


Fig. 11. Turbine and Three-Stage Centrifugal Pump.

nothing so far for repairs. A more comprehensive analysis is furnished by quoting from the customer's letter:

> "The repairs on the turbine-driven centrifugal feed pump installed in 1909 have been $8.00 for new babbitts. It has been in constant operation, and the throttle has been closed only two or three times, the total stoppage amounting to less than three hours in two years or more.
>
> "The repairs on two outside packed plunger pumps have averaged $376.58 for the past three years. They now need extensive repairs.
>
> "The engineers in the station have developed a dislike for plunger pumps due solely to the record made by the turbine-driven centrifugal pump in our own station. The principal items on the repair account on the plunger type of pump, are

packing boxes, new valve parts and machine work on old valve parts. We find that the four boxes on each pump have to be packed about five times each year at a cost of about $10.00 each. This makes an item of $200.00 for packing alone, or $400.00 for both pumps. You of course understand that the pumps have to be lubricated, and as it is our practice not to let any greasy exhaust get into our feed water, all the exhaust from these pumps is put through a closed heater. With the turbine-driven pump, there is no oil in the exhaust, and this we put into an open heater, thereby making considerable saving over the operation of the plunger type, even if we admit that both types take the same amount of steam. It is our opinion that the turbine-driven pump takes considerably less steam for the same service, but we have made no tests and have no figures of our own to substantiate this. Roughly I would say

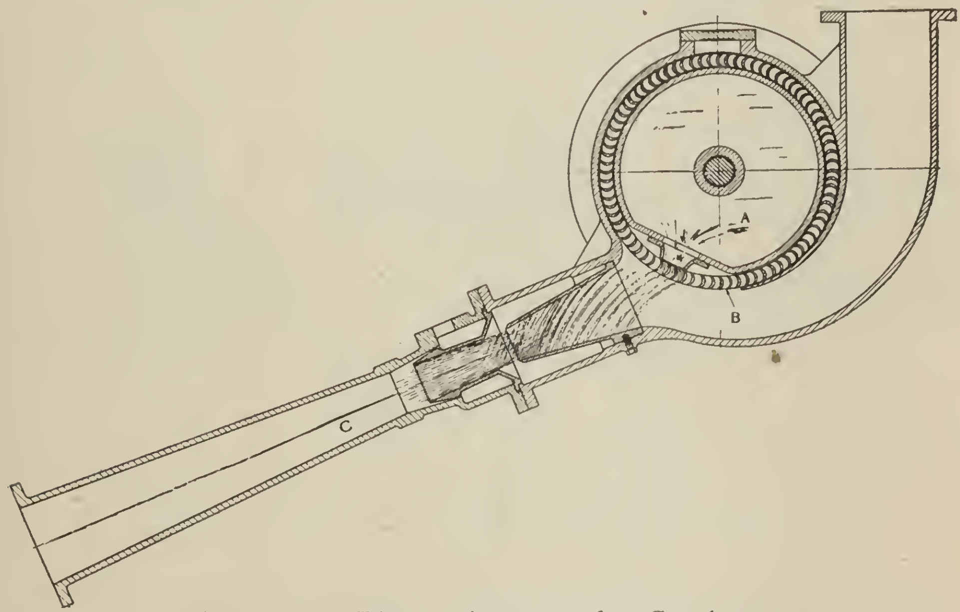
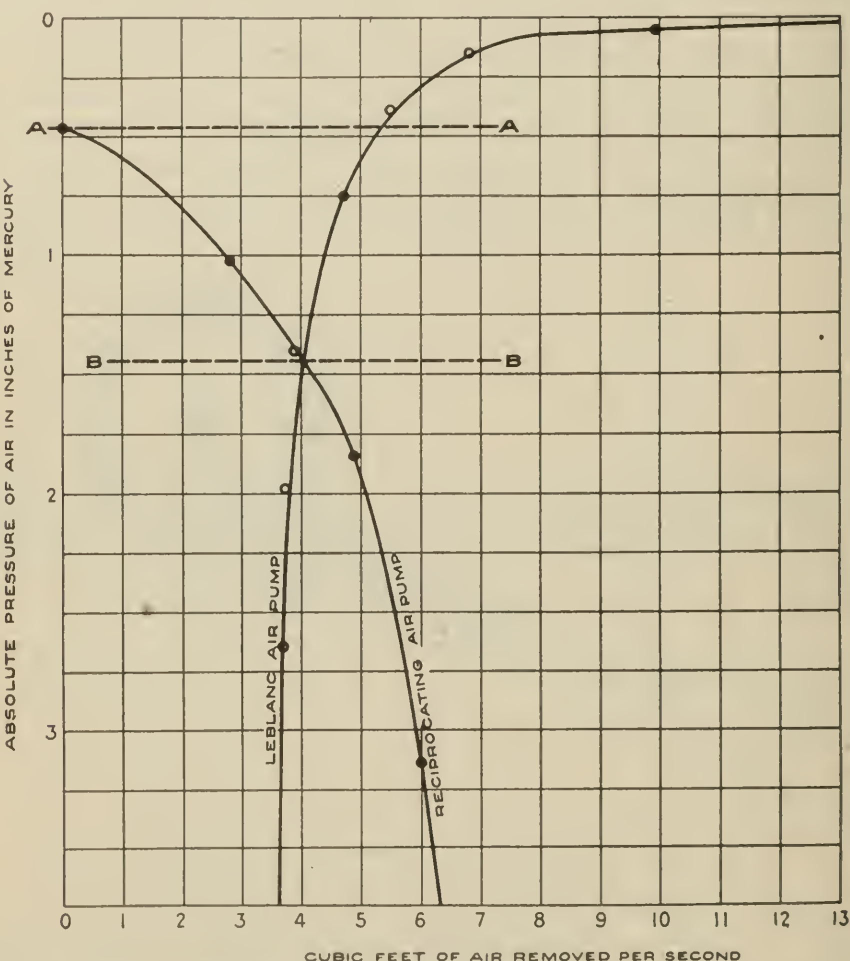


Fig. 12. Le Blanc Air Pump for Condenser.

that the turbine took 4/10 as much steam as the plunger pumps for the same duty."

A turbine-driven vacuum air pump evidently involves the most radical departure from preceding power-plant practice. An air pump employing water jets or sheets to eject or evacuate the air from the condenser was invented by M. LeBlanc, and is capable of being operated at the high speeds suitable for direct connection to small turbines. The principle is simple. An impeller, *B,* Fig. 12, with shallow blades, imparts a high velocity to sheets of water collected in passing the nozzle *A,* and which, ejected into the air passage, entraps layers of air. By means of a diffuser its velocity is transformed into pressure, forcing the mixture of air and water out against atmospheric pressure, or a somewhat greater head, as the case may demand. The advantages of this type are quite

plain. We again evade the necessity of closely fitted parts and rubbing surfaces, requiring lubrication and frequent adjustment and the separation of the oil from the exhaust steam where used in connection with an open heater. As there are no reversals in operation, the harmful effect of clearances in the reciprocating air pump is avoided and a low absolute back pressure may be maintained. The operating characteristics of the LeBlanc and the recip-



CURVES SHOWING COMPARISON OF AIR REMOVED BY RECIPROCATING AIR PUMP AND LEBLANC AIR PUMP

Fig. 13. Curves Showing Performance of Pumps.

rocating air pumps are divergent, which may be best illustrated in the manner shown in Fig. 13, determined from actual test. Above the line *AA* the LeBlanc pump would always be superior to the reciprocating pump, even if its power consumption were in excess. If the latter were identical in the two cases, the LeBlanc pump would always be more efficient when working the region above *BB*, and inferior below *BB*. The conditions for high vacuum service are generally such that the air tensions to be maintained are above *BB*,

so that the question of power consumption is therefore not the final criterion. The question of air tension maintained, must also be considered.

Where condensers are used with steam turbines, the ½ in. lower air tension which would be secured with the LeBlanc pump, would result in a decrease of 2% or more in the steam consumption of the turbine. This (considered together with the use of the auxiliary exhaust in the feed water heater) may closely compensate for the whole power consumption of the condenser.

The general conclusion to be drawn from both theory and practice is that for high vacuum performances, the LeBlanc pump, on account of the characteristics shown in Fig. 13, in nearly all cases will show a net saving in plant economy, either by giving a better vacuum for the same power as would be required by a reciprocating pump, or by the reduced air tension in the condenser,

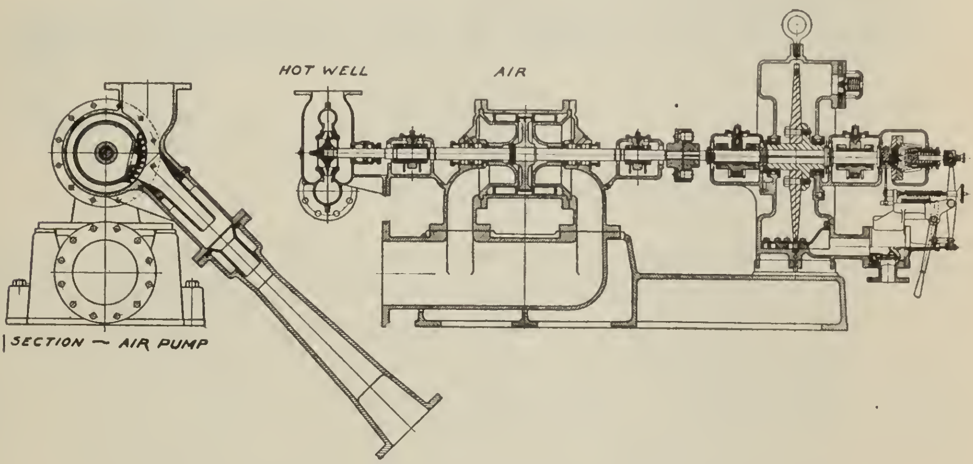


Fig. 14. Hot Well Pump—Condensing Apparatus.

making it unnecessary to circulate as much cooling water to maintain the same vacuum. As an illustration, it is of interest to review the facts brought out in a recent installation of a surface condenser plant equipped with a LeBlanc air pump. In this particular plant, high vacuum was desirable as the condensers are to be used in conjunction with steam turbines. The reciprocating air pumps were giving fairly good results, but were not quite large enough, and it was decided to install greater pumping capacity, either by putting on larger air cylinders, purchasing a new reciprocating pump, or installing a LeBlanc air pump. The LeBlanc air pump for this work, while requiring 40% more power, had a capacity substantially the same as the reciprocating pump for a vacuum of approximately 28 in. of mercury, but with 29 in. of vacuum, its volumetric capacity was practically three times that of the reciprocating pump, characteristically brought out in Fig. 13. The net result was that the LeBlanc pump enabled the maintenance of half an inch better

vacuum under winter conditions, so that the bettering of the economy of the prime mover far offsets the slightly increased power consumption of the LeBlanc air pump over that required by the reciprocating pump.

The unit shown in Fig. 14 has a hot-well pump attached, and

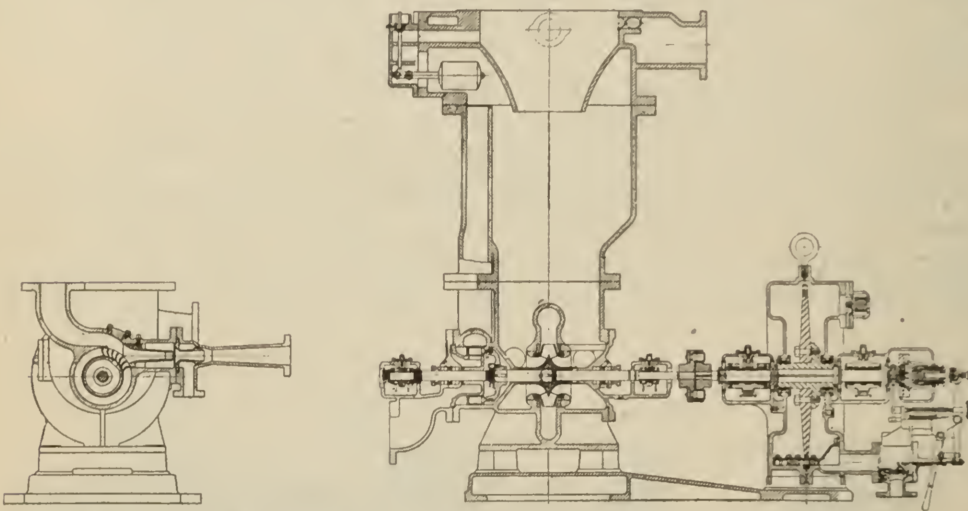


Fig. 15. Le Blanc Pump with Low Level Jet Condenser.

would be employed in surface condenser work, or, without the hot-well pump, for barometric condensers. Heretofore the LeBlanc air pump has been more commonly employed with low-level jet condensers, Fig. 15, showing an improved type especially designed to embody this principle. This equipment may be neatly tucked away beneath the turbine, and thereby occupies no space outside of the boundary of the turbine proper, as the layout appended shows.

MECHANICAL DRAFT.

In the past, mechanical draft has not met with universal favor for boiler-plant operation. A new condition is rapidly coming to the fore, manifesting itself in the nature of forcing boilers to double and even more than treble their accustomed ratings to accommodate peak loads and still maintain good efficiencies in the boiler house during the hours of light load on the plant. High rates of driving boilers require forced draft. In the main, large "paddle wheel" fans driven by small high-speed engines. have been used in this service. The same trend which has influenced the replacement of the reciprocating engine in other classes of auxiliary work, has already been observed in blower operations. On top of the other common advantages of the turbine which have been noted before, the shaking and racking of the blower casing, ducts and supports, are removed. The blower in its old form proves itself deficient for connection with the turbine in the present state of the art. A shallow blade construction with guide vanes for low pressure (as shown in the

upper part of Fig. 16,) propels the air with the least losses and power consumption. The vertical type is exhibited to indicate the flexibility of the turbine application. This specific design has been prepared for use aboard United States torpedo boat destroyers, for forcing air under pressure into the boiler room. A down-draft duct from the deck connects with the blower intake, and the discharge is made directly into the room. The turbine in this position

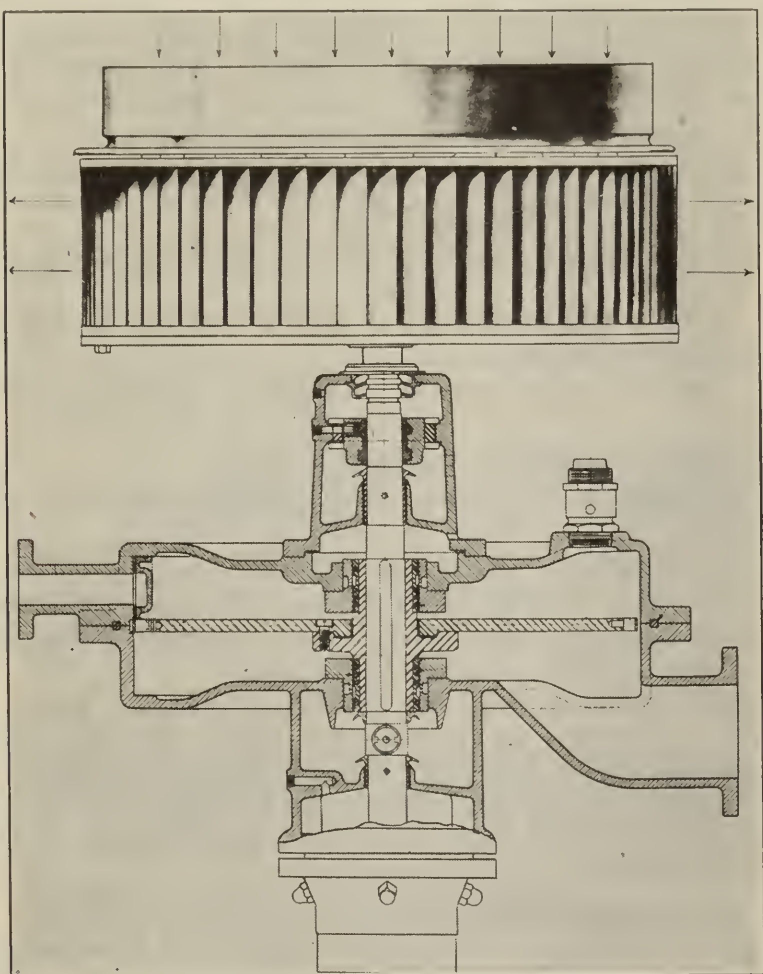


Fig. 16. Turbine and Fan for Forced Draft.

is most accessible, and it is also evident that this arrangement requires but a minimum of duct lengths and bends. In a similar way some special problems in land practice may arise and be met by a corresponding design, although with the latitude permitted in power plants, a more standard construction will be unquestionably adopted.

EXTENDED UTILITY OF THE TURBINE BY PERFECTION OF THE LARGE REDUCTION GEAR.

Use of reduction gears in turbine work dates back to the introduction of the de Laval turbine in 1886. These, however, were

of small size and of the solid-bearing type. Where the power transmitted becomes of any magnitude, with dimensions correspondingly increased, the minute errors in gear cutting may greatly magnify or intensify the unit pressures on the teeth with excessive wear or fracture resulting. A compensating element must then, necessarily, be provided. The development of the Westinghouse reduction gear, which was instituted in 1904, has had for its essential feature the carrying of the pinion in a floating frame which prevents the concentration of abnormal pressures at any one point by automatic readjustment of its position. This gear has already been described at great length in preceding articles* and its detail, therefore, will only be treated generally in this paper.

The important structural and operating features may be understood from the following summary:

(1) Self-aligning, hydraulically-supported floating frame for pinion.

(2) Pinion frame pivoted at center bearing on fulcrum, permitting small oscillations.

(3) Hydraulic pressure in cylinders a measure of the power transmitted.

(4) Spray lubrication for gear teeth.

(5) Divided helical gears cut right and left-hand, neutralizing end thrust.

(6) Teeth of gear cut in special steel rim mounted on spindle.

(7) Depth of mesh easily regulated by hand adjustment.

(8) Flexible driving shaft extending through hollow pinion.

(9) Flexible disc coupling to turbine.

A detail section through the pinion and floating frame is given in Fig. 17. The most interesting feature of the gear lies in the means provided for preserving line contact of the teeth and the automatic adjustment of any slight wear which may occur. This is done by carrying the pinion shaft in a three-bearing frame, supported by hydraulic pressure beneath each bearing. The frame itself is rigid and is split horizontally to receive the pinion.

On the lower side of the pinion frame, and cast integral with it, are the three cylinders above referred to, and into which project short stationary pistons resting upon planed pads of a girder cast into the gear frame. Oil pressure is led to the space over the upper surface of the pistons through passages cored out in the pinion frame, and which communicate with all three cylinders, establishing uniform pressure. Hence any inequality of tooth-bearing pressure would be conveyed to the pistons and thus instantly neutralized.

The prominent use of the geared turbine will be in connection with:

(1) Large direct-current generators.

*H. E. Longwell in the *Electric Journal* for January, 1912.

(2) Large centrifugal pumps.
(3) Large slow-speed propellers.
(4) Rolling mill trains.

DIRECT CURRENT SERVICE.

While there have been many large direct-coupled direct-current generators built, especially abroad, such skillful attendance is necessary that they cannot be so far termed a complete mechanical success. There is no room for argument that the best efficiency is sacrificed by a compromise in the design of the two elements, and this plainly opens up a large field for the geared unit. Contrary to ordinary expectation the length of the complete direct-current unit is not increased in placing the gearing between turbine and generator, and principally for two reasons: First, the length of the high-speed turbine is much less than a lower revolution machine of equal capacity; and second, a high-speed, continuous-current gen-

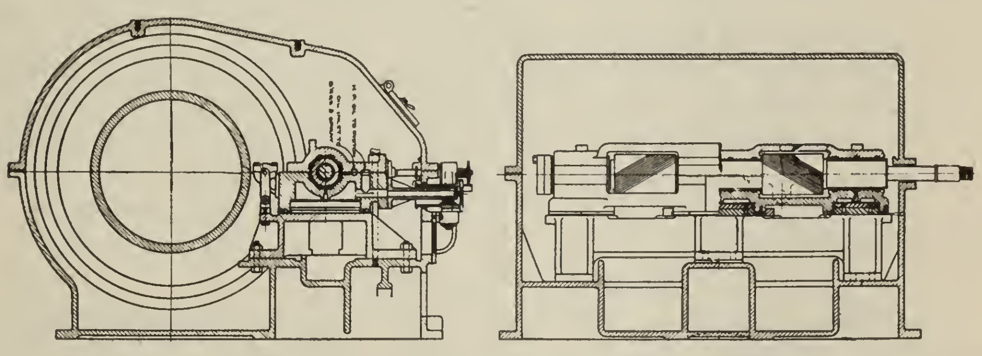


Fig. 17. Arrangement with Reducing Gear.

erator for direct-coupled units requires a long, slender commutator. Direct-current geared units as large as 1,000 kw. are now successfully operating in railway service with a turbine speed of 3,600 r. p. m.

CENTRIFUGAL PUMPING.

Undoubtedly further use will now be made of the large turbine-driven centrifugal pumps by reason of advances in economy resulting from the introduction of the reduction gear. Direct drive has, however, been applied to this class of service, an example of which may be found in a municipal pumping plant in Canada, where two 1125 h. p. 1500 r. p. m. turbines were installed in 1906. Another installation of this kind was made comprising an 1800 r. p. m., 6506 h. p. turbine and centrifugal pump. The latter did not experience a very large measure of success owing to the high speed employed, and accordingly has since been removed, a generator being substituted for the pump and an electrical load supplied.

An interesting installation of a pumping unit having a reduction gear interposed, has been in operation for some time in an

eastern steel mill. The pump is driven by a 700 h. p. low-pressure turbine, as this application was the most profitable use to which the surplus exhaust steam could be turned. A reciprocating pump, under the existing conditions, would obviously have worked in very poorly. Well-designed triple-expansion engines ordinarily have a duty of 150,000,000 ft.-lb.* per 1000 lb. of steam (150 lb. dry-saturated), while the direct-coupled turbine and pump may show only about half as good a performance as that of the reciprocating type.

The 750 h. p. low-pressure outfit, when operating with 27 in. vacuum, has been guaranteed to develop a duty of 52,074,000 ft.-lb. per 1000 lb. of dry saturated steam supplied at a pressure of 15 lb. absolute. The pump is designed for an efficiency of 75%, and the gear is included at 97%, a water-rate of 28.6 lb. per brake horse power having been used in determining the above duty. With a complete expansion turbine driving through a gear, the combination would attain a result of about 110,000,000 ft.-lb., and probably 120,000,000, or better, with a greater pump efficiency, which we believe possible—an interesting approach to the triple-expansion engine above noted. In cases where the pumping equipment is to be operated intermittently, the commercial economy of the geared-turbine set should become superior, owing to its lower first cost and repair charges, considering its inherent simplicity as compared with, for instance, the vast number of small deck valves employed on the reciprocating unit.

MARINE APPLICATION.

Turbines were first introduced into marine vessels in 1894 when the "Turbinia" was so equipped. The trials of this ship pointed definitely to the practicability of the turbine for this service, and the results have been so favorable that there have been installed, to date, an aggregate of over 6,000,000 h. p. of turbines in marine service, embracing all classes of war vessels, merchant marine and pleasure yachts.

It should be noted that in the impressive capacity represented by marine installations, all turbines have been direct-coupled to the propellor shafts, with possibly one or two exceptions. Notwithstanding the remarkable recognition already accorded the marine turbine, it must be acknowledged that the turbine has in these cases been installed under a disadvantage. Again, there is a compromise of speeds between that of the turbine and propeller, such that their designs and efficiencies are prejudiced when direct-coupled. It is not surprising, therefore, that the experience of the U. S. Navy Department has not come up to expectation. Records show that propellers for engine and turbine driven vessels have developed coefficients of 65% and 53.8% respectively, evidently handicapping the turbine where direct drive is employed, and little

*Highest record with superheat, reheating and steam jacketing, 184,476,200 ft. lb. Philadelphia pumping station.

if any has been gained in weight, space, and efficiency owing to the bulk and poor steam distribution required by the low speeds. Space will not allow of a more critical discussion of the subject at this time, but the reasons before cited show that we may with surety look forward to the marine turbine being given a new standing and fresh impetus through the interpolation of the reduction gear.

The effect of the increased efficiency of both turbine and propellor in a marine installation has even a more far-reaching effect, as a large reduction in coal bunker capacity is also brought about, and moreover the boiler horse power required is reduced approximately one-third. The saving of one-third of the space occupied by these boilers will be seen to be a very large item. As each of these ships carry 192 firemen and 123 trimmers, the reduction of the number of boilers to be fired, would effect a material reduction in the expense for this part of the crew.

There is another consideration which deserves mention, viz., if the increased space made available by the reduction in boiler and engine room and bunkers could not be profitably used, the general proportions of the vessel might be decreased, which would immediately have an accumulative effect and again reduce the amount of power required for propulsion.

The requirements for war ships are very different from those of fast passenger ships which run normally at full speed, as war ships run at full speed only in case of emergency. When cruising, they use less than one-fourth of full power. As the efficiency of the existing marine turbine rapidly falls off at reduced (rotative) speeds, the steam consumption per horse power hour becomes serious when the ship is running at cruising speed. The desideratum is, therefore, a turbine capable of performing economically at both cruising and full-speed.

The United States Government is now conducting extensive trials of this method of propulsion and the result will be publicly reported in the near future. The improvement which will be effected will be of the nature already denoted.

The reduction gear now brings the lake steamers and slow-going vessels within the domain of turbine application, and it is not unreasonable to presage that marine engineering will be revolutionized in the immediate future in a manner similar to that wrought by the turbine in stationary practice. There is, besides the mechanical application, an hydraulic and electric system which have been tried out in marine work, but these are inherently inferior in both operation and efficiency. The hydraulic or Fottinger gear has been tested in Germany and within the last few months the United States Government has contracted for electrical equipment in order that competitive trials may be conducted and comparisons drawn with the geared outfit.

May, 1912

ROLLING MILL SERVICE.

With the turbine now being used in the rolling mill by mechanical coupling to the rolls through gears, it has successfully encroached upon every important field of application of the reciprocating engine, with the exception of the reversing, hoisting, and rolling-mill service. While the reversing marine turbine is now an actuality, yet it is a problem whether the turbine will become a factor in stationary reversing work, especially in small sizes. As the matter is of direct interest in connection with the development of the large power reduction gear, the essential facts of the geared turbine rolling-mill installation of the Calderbank Steel Works, Scotland, are reproduced, together with a plan of the layout. These were discussed at length in a paper entitled, "The Application of a Geared Steam Turbine to Rolling Mill Driving," by Mr. A. Quentin Carnegie, published in the Journal of the West of Scotland Iron and Steel Institute, Vol. XVIII, p. 193. Extracts from this paper follow:

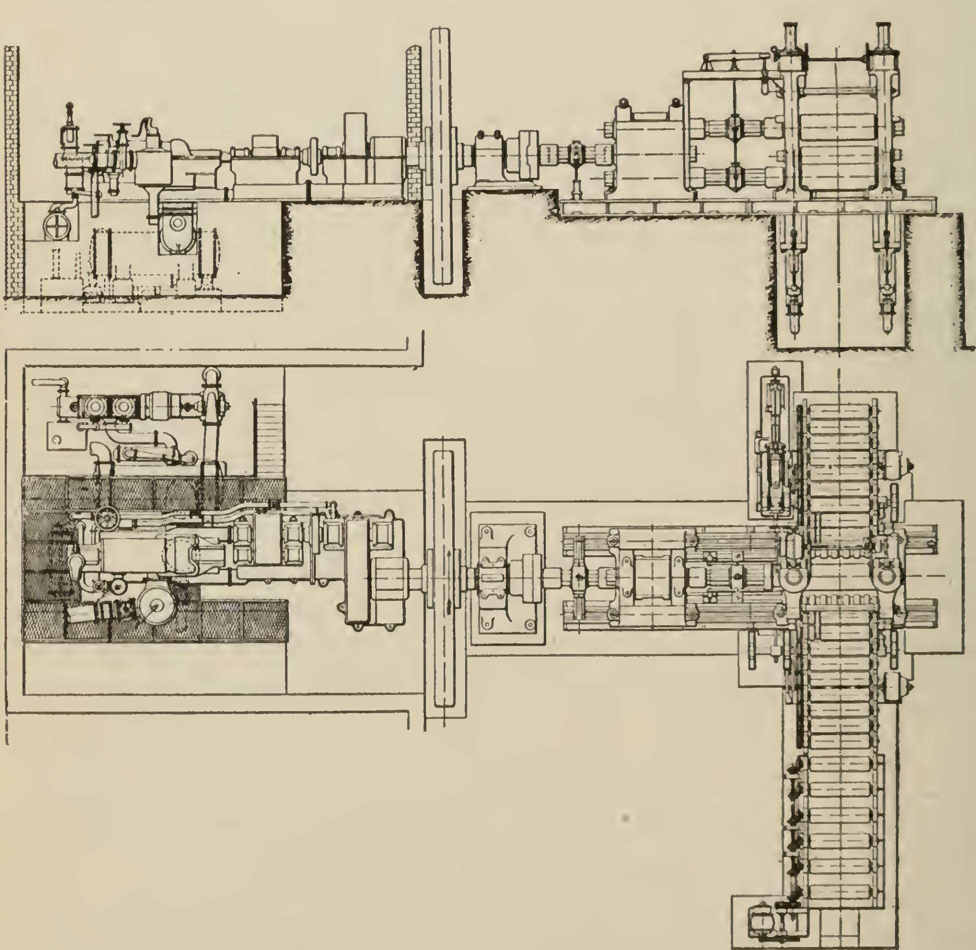


Fig. 18. Turbine Applied to a Rolling Mill.

In Fig. 18 is shown the general arrangement of the installation in elevation and plan. The steam turbine is of the Parsons mixed-pressure type and is designed to run at 2,000 r. p. m.

"The mill runs at a speed of 70 r. p. m. and the speed of the turbine is reduced from 2,000 r. p. m. in two steps, the intermediate shaft running at about 375 r. p. m."

"Both pairs of gears are arranged in cast iron gear cases, which are provided with suitable white metal lined bearings for the shafts."

"Flexible couplings are fitted between the turbine and the high-speed pinion shaft, and also between the first and second reduction gears. The couplings allow for small errors in the alignment of the shafts, and also give the necessary end freedom for expansion of the steam turbine shaft."

"The first slab was put through the mill on September 15, 1910, after the whole plant had been run slowly for several days, to allow the main bearing to settle down into working order."

"Up to thirty slabs have been rolled in an hour, and the maximum size of the plate has been 60 ft. long by about 6 ft. wide, with a minimum thickness of $\frac{3}{16}$ in. The lifting tables for some time worked too slowly, but they have now been speeded up, and take six seconds for the lift and fall."

"The general experience which has been obtained with the working of this plant is sufficient to show that the experiment has proved a most gratifying success. The mill has been working regularly ever since the heavy bearings have settled down into good working order, and no trouble of any sort has occurred."

"Referring now to the future fields which these two important experiments have opened up, the writer sees no difficulty in applying turbines to the driving of textile mills or other works which require large powers. The geared turbine will easily give the absolutely uniform speed of drive on which advocates of electric driving for cotton mills based all their claims, and it will give this without the intervention of electrical machinery with its power losses and heavy capital cost."

ADDITIONAL FIELDS OF APPLICATION.

For the reasons which have made the turbine prominent in the applications previously mentioned, new fields have been constantly opening up for this interesting prime mover. Some important ones may be noted:

(1) Low duty pumps.
(2) Air or gas compressors.
(3 Train lighting sets.
(4) Locomotive headlighters.

AIR AND GAS COMPRESSION.

One of the latest invasions into the stronghold of the reciprocating unit has been the building of high pressure centrifugal compressors. In the past, neither the centrifugal pump nor compressor have been considered as being practical for high head work or pressure, owing to the poor showing made of the early types. The fundamental theory of centrifugal design has not heretofore been sufficiently understood and appreciated so that we are just awakened to the unusual possibilities of the centrifugal unit for this service.

Analysis of preceding constructions will show the entire lack of regard of the necessity of converting the kinetic energy repre-

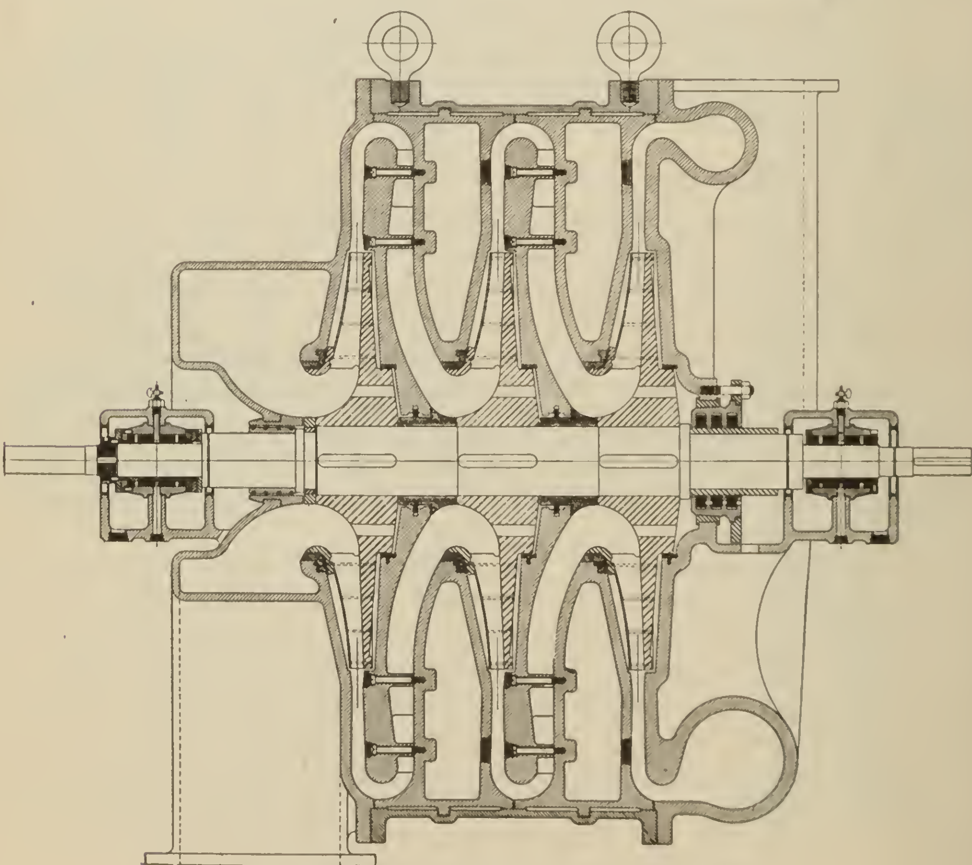


Fig. 19. Turbine Applied to Air Compression.

sented by the final velocity into potential energy, so that 50% of the energy was lost merely in this way without reckoning the other losses attending its operation. There are several methods of effecting this conversion, i. e., diffusion valves, volutes of proper design, and diffusion tubes or inverted nozzles, and the application of these is governed by the nature and extent of operation. Hence with proper designs, efficiencies of 65% to 90%

are obtainable. Details of a high efficiency compressor designed for moderate pressures are given in Fig. 19. Several single impellers (as shown) may be placed on a common shaft and operated in series, each imparting an equal amount of energy to the air, and thus serially building up the pressure. Each succeeding impeller raises the pressure to a higher degree than in the preceding stage, as may be quickly grasped in dividing up the compression card into equal divisions of work. Or, in other words, since the energy expended in each stage is the same, the pressure difference must be greater, inasmuch as the volume delivered to the following impeller is less, owing to its higher pressure. This follows from the formula $PV^n=K$. The noteworthy features of the multi-stage compressor is that the efficiency of the series of impellers is the average of each independent wheel; losses are not cumulative as may be supposed. Blowers of this type may be conveniently built

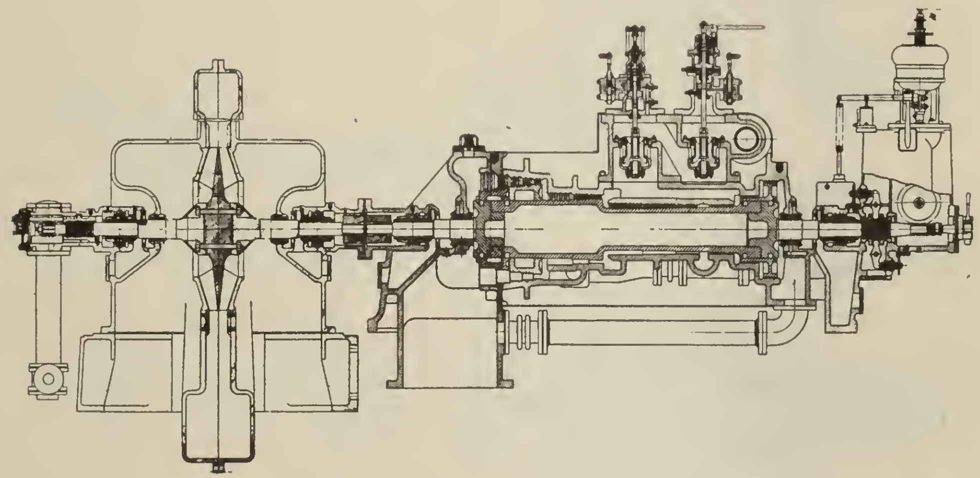


Fig. 20. Turbine and Centrifugal Compressor.

in sizes impractical in the reciprocating design. Freedom from pulsations and vibration in the system is a large factor in their favor, and foundation requirements also may be found to be a weighty consideration. The other advantages, reduced attention, oil, and costs are evident with centrifugal construction.

Compressors of this type containing ten more stages are readily built for pressures of 80 to 100 lb.

It so happens that the centrifugal compressor in Fig. 20 has been connected to a 700 h. p. reaction turbine of 3,600 r. p. m., and is correspondingly represented by sectional detail. This is probably one of the most familiar of turbine sections to engineers in general, and there is warrant in remarking that for this capacity and speed the design has proven itself most efficient mechanically and thermodynamically.

May, 1912

LOCOMOTIVE HEADLIGHTERS.

There are certain railway systems, especially single-track lines, which require special safety measures in order to operate fast trains and maintain schedules. A most interesting application of the turbine responds to this small self-contained generating set, mounted on the engine, either above the boiler or on the pilot. This penetrating light may be distinctly observed, in a line of unobstructed vision, for a distance of over a mile at night, and the radius of the engineer's sight extends 3,000 ft. ahead. Warning of danger ahead is therefore given in time to escape or avert accidents.

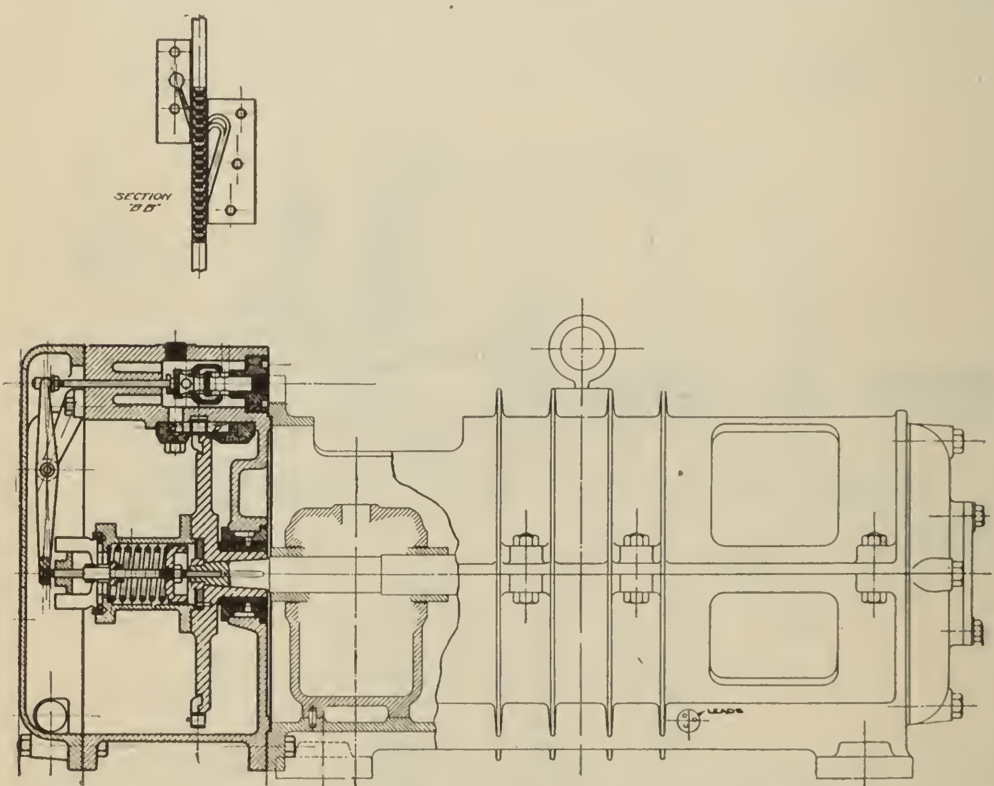


Fig. 21. Turbo-Electric Machine for Locomotive Headlight.

It is no doubt understood by many that a number of states have enacted laws compelling trains to be equipped with an electric headlighting set, or other high candle power lamp, and the greater safety along these highways is evident. Reliability is therefore most important, and the simplest and most dependable mechanisms are demanded. Fig. 21 illustrates how some of the designs previously described have been reduced to such a satisfactory state. All parts of the turbine and generator are totally enclosed and therefore weatherproof. The unit is but 3 ft. in length and develops 1 kw. at 4,000 r. p. m. using about 185 lb. of steam per hour.

TRAIN LIGHTING.

Generating equipments driven from the axle of the car wheel, have been used for this service, and possess some advantages, but are plainly very complicated and undoubtedly require a high degree of supervision to maintain them at reasonable cost. They are possibly best suited to trains making short local runs, and in any case. where the make-up of the train is subject to frequent change, to avoid making and breaking electrical connection between successive cars. The storage-battery outfit is the simplest installation, but the chief objection to this type is to be found in the attention required and the provisions for charging necessary at the terminals.

Steam-driven generating sets are the next in simplicity, and probably form the most practical solution of the car-lighting problem. Reciprocating steam engines have been used to some extent,

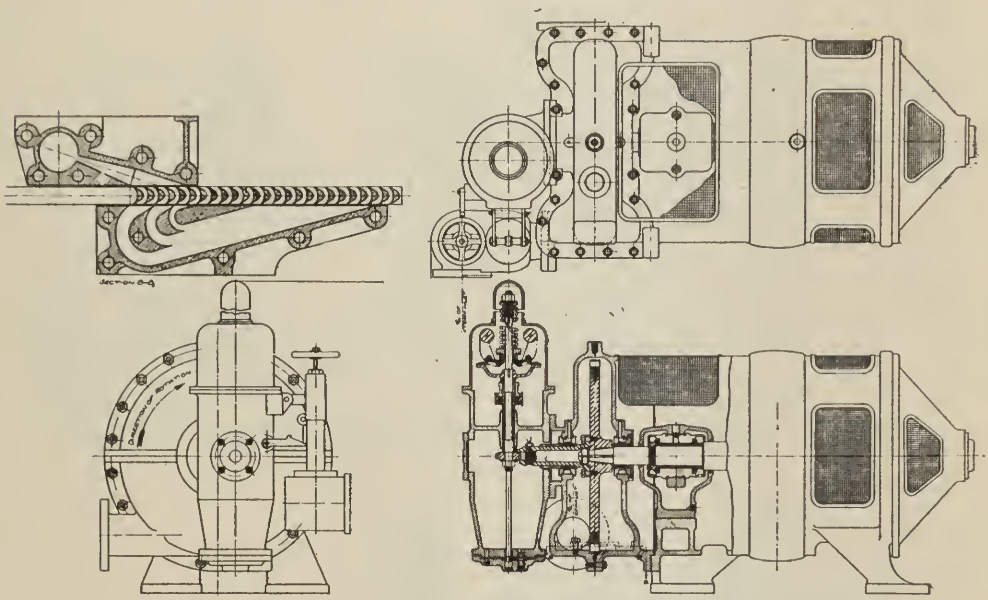


Fig. 22. Turbo-Electric Machine for Train Lighting.

and while their economy in units of small size is somewhat superior to that of the turbine, the latter is to be preferred owing to its quiet operation. Units for such service are generally installed in the baggage car, and in the absence of heavy foundations, the reciprocations of the engine may be felt throughout the entire train and have proved very annoying. The turbine, on the other hand, is inherently quiet-running, and, moreover, its small floor space requirements possess a real value in this particular service. A turbine-driven equipment, as shown in Fig. 22, would obviously prove best for long distance "through" trains, all coaches being on one electrical circuit supplied from the single source.

The greatest advantage of the independent steam unit evidently lies in the possibility of maintaining continuous operation for any

period, regardless of whether the train is in motion or at rest. This characteristic will be appreciated by those who have experienced prolonged delays in darkened cars.

SOME NEW TYPES OF INSTALLATIONS.

For straight condensing operation, Figs 23 and 24 show economical layouts as regards piping connections and compact ar-

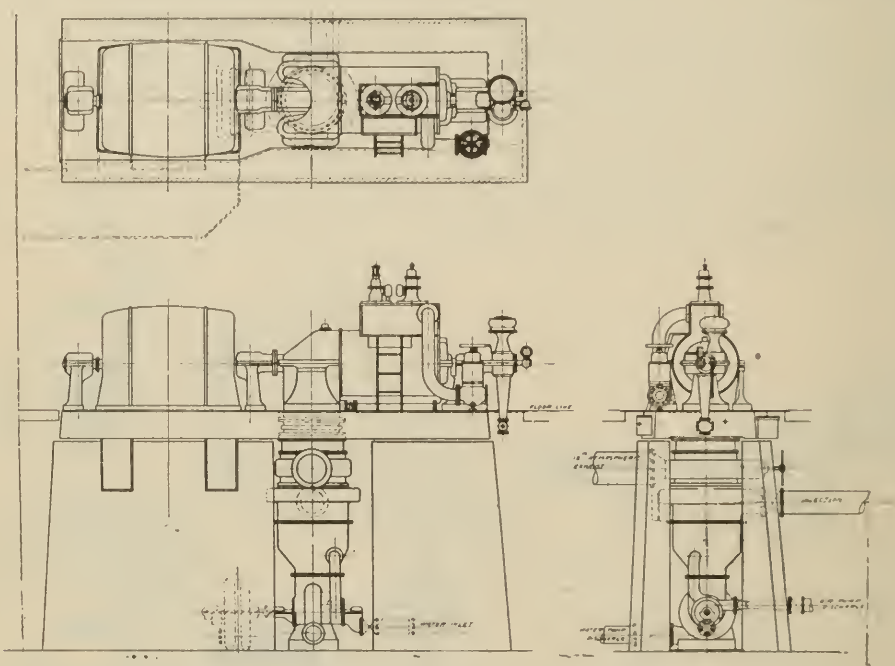


Fig. 23. Turbine Condenser Apparatus.

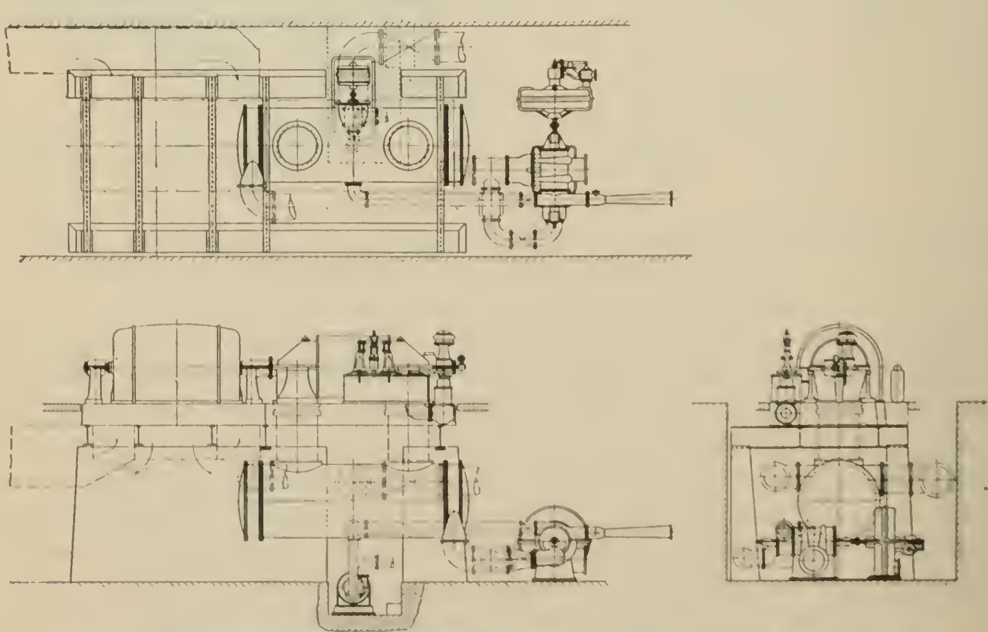


Fig. 24. Turbine Driven Pumps for Condensing Apparatus.

rangement of condenser and auxiliaries directly beneath the turbine, obviously avoiding their location in the path of travel. Fig. 24 is of particular interest, as it shows how simply and effectively turbine-driven air and circulating pumps may be applied to surface condenser work and the minimum floor space requirements.

In Fig. 25 is represented a typical layout of a central station equipped with an automatic bleeder turbine serving a combined heating and electrical load. As to be noted, the arrangement of piping is exceedingly simple, the exhaust and bleeding connection from each unit delivering into common headers which lead respectively

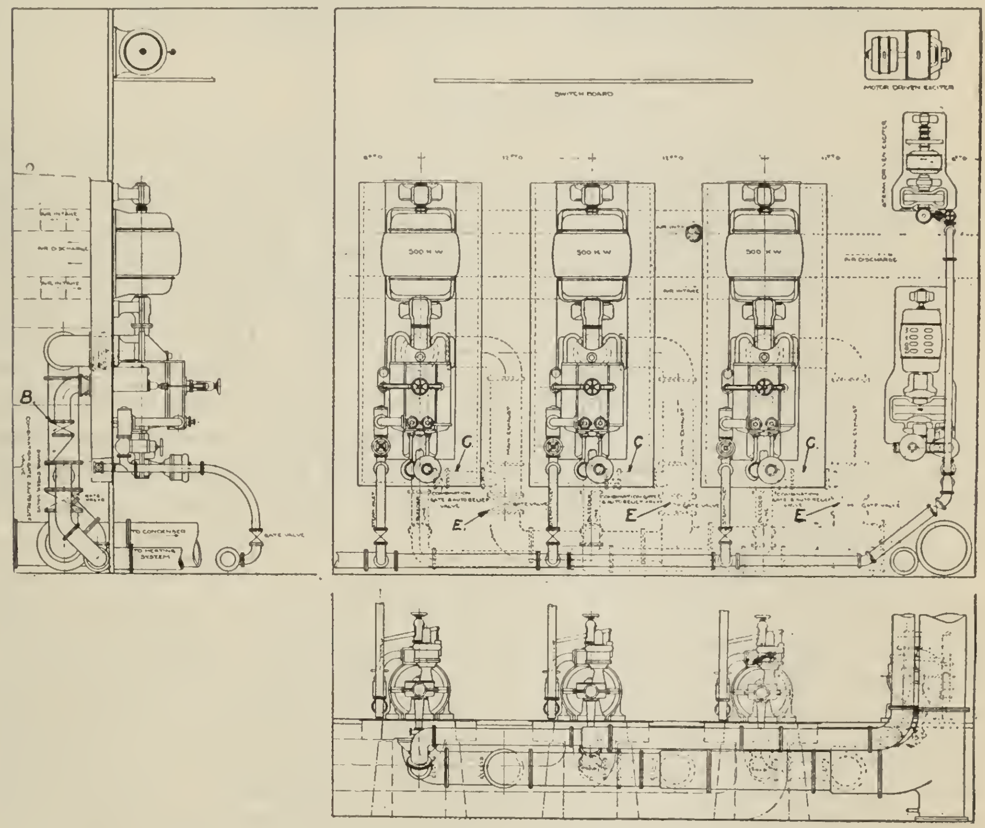


Fig. 25. Station Layout, with Bleeder Turbine.

to a central condenser and the heating system. In some installations it may be the desire to divert all the steam from the turbine into the heating system. If the turbine is fairly well loaded, as it probably would be under these circumstances, it would prove more economical to have the steam pass through the entire turbine, providing none escapes to atmosphere. This could easily be accomplished by introducing gate valves *B* and *E* in the main exhaust and bleeder lines from each turbine and the interconnection *C*. Then to run the low-pressure stage non-condensing, passing all steam to the heater system valves *B* and *E* would be closed and the valve in

connection *C* opened. With the automatic bleeding operation, as normally obtains, *B* and *E* are open and *C* closed. Operating strictly condensing, *B* and *C* are closed, *E* obviously being wide open, and the automatic valve on the turbine raised out of action.

CONCLUSION.

In attempting to outline the numerous developments which have taken place in the turbine art in the past few years, one is compelled to omit many features which bear great interest, in order to avoid a discussion of greater length than at present desired. It is hoped, however, that the facts which have been herein set forth will lead to a further study of these significant subjects.

DISCUSSION.

W. L. Abbott, M. W. S. E.: The engineers in the design and development of electrical apparatus, have justly the credit of being the most energetic and the most scientific, in developing the science relating to their particular art. Next to the engineers who have had to do with electrical apparatus come the engineers who have had to do with the development of steam turbines. If you will reflect upon the short period which has elapsed since the steam turbine first became a commercial product, and consider the development which has taken place in that kind of apparatus since that time, and compare it with the development which has taken place in the reciprocating engine through the century which preceded, you will at once see that this is true.

The first steam engines were of what we would now consider remarkably slow speed—as low as two or three revolutions per minute. Since that time the trend of the art has been to increase the speed. Steam at high pressure or moderate pressure will travel and do its work at almost the velocity of a rifle bullet. The utilization in practice of this fact was impossible with any piece of mechanism which necessitated starting and bringing to rest a great mass of metal within a fraction of a second, and it was not until the development of the steam turbine that the engineer began to realize the possibilities of the high speed of steam. The speed of the reciprocating parts of a steam engine is from 10 to 15 ft. per second. The speed of the revolving parts of the turbine is from 200 to 300 ft. per second.

The weight of these two prime movers for the same power is nearly in inverse proportion to their respective speeds, and although the price per pound of large turbines is three or four times the price per pound of large engines, the total cost is much less. This shows why so much more power in turbines can be put into a given floor space than is possible with reciprocating engines, and why few large size engines are now being built.

The Westinghouse company, as we have learned this evening, has been doing its part for the development of the art of steam turbine practice, not the least of which are the two devices which have been shown—one, the air pump which ejects the air by putting a small volume of air in front of a plug of water which is thrown through a narrow throat at high velocity; and the other, which I think we shall hear much more about in the few years immediately to come, is the development of the gear which was designed by Admiral Melville. The application of this gear to marine engineering is a great step in advance. Large slow-speed propellers are more economical than small high-speed propellers. With a propeller shaft directly connected to a steam turbine, it is necessary that the size of the propeller be relatively small, because the speed of the shaft must be very high. That is the principal reason, as the speaker brought out, why the direct application of the steam turbine to a vessel propulsion has been a disappointment. The new gear which permits of a reduction of speed in any desired ratio permits the use of a high-speed turbine, with its accompanying economy of steam and space, with a slow-speed propellor, thus reducing the number of propellers which are necessary when a high-speed turbine and propeller are used.

Harold Almert, M. W. S. E.: In the latest-designed units of 10,000 or 12,500 kw. capacity, under average conditions what percentage of total power generated is required by the auxiliaries, and what is the difference in amount of auxiliary power required for the surface condenser and the LeBlanc condenser? Further, what is approximately the number of pounds of water required to condense a pound of steam in the case of the more recent surface-condenser outfits, as compared with the LeBlanc outfit?

Mr. Dreyfus: The amount of auxiliary power that is required for a 10,000 or 12,500 kw. outfit depends entirely upon the condenser auxiliary arrangements; i. e., what one may choose or find it necessary to select. Conditions are so variable that if I did give you an answer you could only depend upon it for some specific example. So many factors enter the condenser problem—coincident or non-coincident levels of intake and outflow temperatures, possibly acid or brackish water, etc. For the station of 10,000 to 12,500 kw., do you mean the capacity of the individual machines, or the aggregate capacity?

Mr. Almert: I mean capacity per unit.

Mr. Dreyfus: With the LeBlanc system it may be about 2½%; with the reciprocating outfit, about 1%, possibly somewhat more; with circulating water and air pump, 2½%; with the surface condenser, 1% to 1½%.

Mr. Almert: That is the air pump only, then, not circulating water as well?

Mr. Dreyfus: Both air and circulating pumps.

In drawing a comparison of this kind, we must carefully differentiate between the surface and jet types. While the surface condenser takes more water, it takes less power to circulate the water on account of the lower head which must be overcome by the circulating pumps. In a jet condenser we have to expel both air and water against a 35 or 40 ft. head. In the surface type, we have only to circulate the water under a 15 or 20 ft. head. It may be that one will desire to test the merits of the surface versus jet types, or else either one or the other designs with different kinds of auxiliaries applied.

Mr. Almert: I realize that, but we will assume some reasonable or average condition. Suppose the water had to be pumped against a total static head of 25 ft. for the surface-condenser conditions.

Mr. Dreyfus: Offhand, I will say such a condition would exclude the surface condenser, but I might mention that the LeBlanc air-pump is now being applied in surface-condenser work.

Then to contrast the LeBlanc and reciprocating pump serving jet condensers, the problem resolves itself into a comparison of the overall performance of the turbine and condenser equipment. While the LeBlanc type probably consumes, in itself, more horse power, it creates a better vacuum in the condenser, owing to the absence of clearance and the re-expansion in the clearance vacuum. Thus a saving in the steam consumption of the main unit is made. So when we begin to balance up the final steam consumption or draft on the coal pile, we have found in many cases that although more power was required by the auxiliaries, the net plant results were much improved.

Mr. Almert: What do you mean by "better vacuum"?

Mr. Dreyfus: I cannot recall any definite quantities, but 3% to 5% is reasonable.

Mr. Almert: Within half an inch of absolute vacuum, or something like that?

Mr. Dreyfus: In terms of vacuum, we realize half an inch or better. When I said better, I meant the total draft on the boiler. including the turbine and auxiliaries, with the exhaust steam and the auxiliaries credited back as to how much steam might be absorbed by the heater. I would like to give you a specific case, but it would have to be worked out independently.

With reference to your other point—how much more water a surface condenser would require than a LeBlanc condenser, you must distinguish this fact: That the LeBlanc condenser is simply a low-level jet with the LeBlanc air-pump feature. Outside of that it comes within the regular jet class, except that in the matter of design we have been able to get it exceptionally compact. Its individuality lies in the use of the rotating water evacuating air-pump.

Mr. Almert: Can you not give a definite figure assuming that the cooling water is 50 degrees in both cases?

Mr. Dreyfus: It is customary practice, and has been, to consider that a jet condenser will take 40 lb. of circulating water per pound of steam, and that a surface condenser will take from 50 to 60 lb. I am sorry I haven't some definite figures of this character with me, but to make an offhand statement would be hazardous, as there are too many factors to be considered.

P. Junkersfield, M. W. S. E. I would ask Mr. Dreyfus what is the probable limitation in horse power that could be transmitted by Westinghouse reduction gears, as near as he can tell from the present state of the art?

Mr. Dreyfus: We are now building gears of 5,000 h. p. and have no hesitancy in doing so. Serious thought has been given to building them for 10,000 h. p. provided we had call for them. It is just a matter of getting the proper cutting machine, which will come about with the experience we are obtaining on the small sizes. We will gradually grow to it. We feel that 10,000 h. p. gears are quite possible within the next few years. The speed of revolution depends upon what may be required. In some of the marine vessels it is 185 r. p. m. for the propeller, and the turbine is 1,200 r. p. m. In one case of a 1,000 kw. D. C. outfit the generator speed was 712 r. p. m., while the turbine ran at 3,600 r. p. m.

Mr. Almert: Has the Westinghouse company tried the worm reduction in any large sizes?

Mr. Dreyfus: What I showed on the screen was the helical type of gear. If I understand correctly, you refer to the solid gear such as the de Laval company employs, which has no floating frame. The helical gears mesh gradually. The teeth do not come in contact abruptly. But the gear in itself—by that I mean the shape and character of the teeth—is no different from the de Laval type, the only distinction being in the floating arrangement. The object of this later feature provides that if the tooth pressures on the right gear become excessively high, the floating frame will be deflected slightly and distribute the proper portion of the load to the left helix.

A Member: Is there a flexible coupling?

Mr. Dreyfus: In order that the floating frame may be unrestricted in its function of equalizing tooth pressures, there is a flexible coupling between the coupling and the turbine shaft. In addition to that, the pinion has a hollow shaft and within that hollow shaft is a long, thin, flexible shaft, which connects with the pinion shaft at the opposite end.

The subject on which I have undertaken to prepare a paper is, you will appreciate, a very broad one, and therefore it has been difficult to compress into a paper of this size all the interesting facts and features which could be brought to your attention. An endeavor has been made, however, to put before you the most essential features, based on our experience at Pittsburg. There has been, as you know, considerable development carried on elsewhere which is correspondingly interesting, but I have naturally confined myself to the work with which I am personally familiar.

ASSEMBLING AND REAMING

TOPICAL DISCUSSION, FEBRUARY 12, 1912.

The Bridge and Structural Section.

W. H. Finley, M. W. S. E.: After the subject under discussion this evening was announced, I heard this remark, "Why, what can be said upon the subject of assembling and reaming? There is nothing new." To be sure, there is nothing new about the matter, but there has certainly been a decided change in shop methods and in the manufacture of structural work during recent years. A good many years ago it was the boast of the American Bridge Company that they could turn one member of a bridge out of one shop and another connecting member out of another shop, send them to South America or Australia, and they would match perfectly. That practice has gradually changed until now there is a decided tendency not only to sub-punch and ream everything, but also to assemble in the shop and drill or ream all connections. In the days of iron it was not considered necessary to do any reaming, and I think the highest stage of perfection in accuracy of punched work was then reached; I doubt very much if as accurate work in that line is now obtained.

My first knowledge of or experience with steel was in the building of the Brooklyn Bridge—a bridge that still stands as a monument to its designers and builders. It was built of high-grade steel at a time when there was little, if any, steel used in structural work. That work was all reamed. However, it was reamed with a tapered, fluted reamer, flexible shaft, and such was the accuracy of the punching that the reaming was only considered necessary to clean out the holes. Now they sub-punch and assemble and ream in place; so that our boast that we could build members in separate shops and send them to the four ends of the earth and put them together, hardly holds good.

In the early days we laughed at the practice of our English brethren in the bridge-manufacturing line, of setting everything up in their shops to be sure it was all right before shipping. Of course, owing to the increased amount of riveted work, this shop-assembling practice is probably more necessary now, than it was in the days when the pin-connected bridge design held sway. My observation leads me to believe that owing to the fact that so many engineers require their work to be assembled, the parts put together, and the joints reamed in place, less accuracy in the punching and in the assembling—particularly in the latter—has resulted. Doubtless there are a number here tonight, who are engaged in manufacturing and who know more about the matter than I do, and they may not agree with me; yet there seems to be a tendency in the shops to hurry through the assembling,—that is, the assembling of the component

parts of a member,—and the punching, with the idea that it is all going to be reamed anyhow.

When iron was gradually being replaced by steel, considerable attention was given to the question of reaming, and there was some doubt and great fear about the change in materials. More or less tests and experiments were made, to show that it would be dangerous if the metal about the punched holes was not reamed away and the incipient cracks removed.

There is no question but that the assembling of these trusses and bridge parts in the yard or shops, and the reaming of the parts, adds somewhat to the cost of the work. Of course, the use of electricity now makes it much easier to move around a drill or punch than in the days when line shafting was used. It is a question, however, whether the extra work that we are putting on structural work by setting it together in the shops and reaming out the rivet holes is really good economy.

I have had occasion to dismantle a large number of old bridges, and do not recall one instance when I discovered that a defect or failure in any part of a bridge was due to imperfect shop-work. It was generally a question of poor design or bad detailing of the joints or connections. My experience with old bridges has been particularly in the last few years, with the riveted lattice bridges that were built a great many years ago, when designing had not reached the state of perfection that it now exhibits. In nearly all the cases where we have had trouble with these bridges, it has been in some faulty detail in lateral or other connections.

With the grade of structural steel which we are now using, the question arises whether it is necessary or desirable to spend the extra money required in reaming, and whether it would not be better to put that amount of money in an increase in sections or connections. I saw some work lately—a rather large riveted bridge —set up out in the yards of a bridge shop, where all the connections of the chords and end posts were being drilled from the solid. There is no doubt that this results in very nice work, so far as the fittings are concerned, but it is necessary in all cases to match-mark such parts and set them up in the field just as they were set up in the shops. In the early days it did not make much difference, as any member of the same kind would go in any part of the structure.

Horace E. Horton, M. W. S. E.: For approximately twenty-five years, reaming has been very generally specified for rivet holes in material for bridge work, with so much earnestness and seriousness that now the shops of the country turning out such work are prepared to ream one-quarter of their usual output.

Mental science has very generally been called into service to accomplish reaming; in fact, there is abundant evidence that the demand is one of fashion, emotion, or from a whimsical, or hysterical basis, and not called for by the actual physical conditions.

With all that has gone before, it is very interesting and instructive to hear Mr. Finley's remarks (his observation having been as extended as any); in fact, his broad statement that he had never known a structure whose efficiency was impaired in the least by faulty workmanship, or by want of reaming of rivet holes, which would, by many, be considered faulty.

Some fifteen years appears to be the life of a railroad bridge, incident to the ever increasing magnitude of loads. I believe I am justified in saying that before an old bridge is removed, it is quite common practice to make a careful study of it, in fact an investigation which invariably turns on the quantity of material in the structure and how well the original design was worked out. On such occasions there is no thought or care whether the material was reamed or not.

From the facts as here stated, it clearly develops that the engineer who uses 20% less material of medium steel reamed than he would of soft steel not reamed, is doing his clients an injury, as it is a well known fact that in practice, soft steel and medium steel are absolutely the same thing. Of the 8,000 lb. range on ultimate strength allowed, medium steel invariably takes the lower 4,000, and soft steel the upper 4,000, and they are physically, in fact, the same thing. In the mortality of old bridges, a bridge designed with higher unit stresses is sure to have the shorter life and give less service.

Engineers, on occasion, demand "workmanship," seemingly to overcome the force of gravity without the use of material. No one has ever known a structure's efficiency to be reduced in any appreciable amount by faulty workmanship, in so far as its riveting is concerned; each one of us has known faulty design to reduce the efficiency and value of important structures to zero. Efficient and economical design represent in value, in a specific structure, at least a ratio 1,000,000 to 1 of workmanship. We have never known a structure to fall down from faulty workmanship; we have all known them to collapse from faulty design. Engineers design the structures and manufacturers execute them to the specifications as to workmanship; any grade of workmanship required will be furnished that is paid for; but to expect workmanship, say reaming, without paying for it, it is needless to say that more or less confusion will follow.

In the twenty-five years that reaming has been so freely specified for bridge work, a large majority of those specifying it really expect to get it without paying for it; calling for it as a thing to be had for the asking.

The subject of reaming has never been specified in such a way that the manufacturers have understood it to mean that real physical reaming was to be done; which is, undoubtedly, the explanation why after twenty-five years they are only prepared to ream 25% of their capacity.

C. F. Lowcth, M. W. S. E.: The speaker is surprised that this question is up for serious consideration at this time. He had supposed it was settled some fifteen years or more ago; at any rate he settled it for himself as long ago as that, and it has been his practice for a great many years past to insist upon sub-punching and reaming.

At the outset, when steel was beginning to take the place of iron, there was some evidence that it was necessary to ream rivet holes to eliminate dangerous checking or cracking of the metal, which might lead to serious results. Later it appeared that this danger was over-estimated, and that for certain limiting thicknesses the injury done by punching was not dangerously great. However, the speaker has come to justify sub-punching, in his own mind, on the score of the better quality of work which it produces.

It is sometimes said that if the work is not to be sub-punched and reamed the punching is more accurately done, and that the finished work approximates as good quality as though it were sub-punched and reamed; this for the reason that the workmen take less care in getting accurately sub-punched work than they do in work which is not to be reamed. The speaker does not believe that this is generally true. Certainly it is not true in the shops which have even a reasonably high standard of workmanship; it ought not to be true in any case.

Of late years the speaker has been inclined to more and more favor the assembling of work at the shop, and while so assembled, to ream all field rivet holes. This requirement certainly makes the work more expensive for the shop, and probably for the purchaser. If it does not cost the purchaser more it is the shop's fault, for the purchaser should pay the additional cost, and the speaker believes that the extra cost for doing this work is fully justified.

Assembling work at the shop, and reaming the field rivet holes while so assembled, insures a better quality of work, and a much greater degree of accuracy of fit in connections. It is perhaps possible to secure the same degree of good workmanship and accuracy by other methods, but they would probably cost as much, and not be so reliable. The fit of connections is always very desirable from the standpoint of the erection of the work in the field, where delays due to misfits or ill-fitting connections are expensive and annoying. This is especially true where the work is being erected on the line of an operated railroad, where traffic must be maintained without any delays during the erection of the work. In such cases it is difficult, oftentimes, to find the two or three hours, or perhaps even less time, between trains, necessary to take out the temporary structure carrying the track, and substitute a panel of the new structure. A trifling misfit, which adds but a few minutes to the time of connecting up the new member, would result in delay and oftentimes extreme annoyance. To prevent this, if there were no other

reason to justify it, the speaker thinks that shop assembling is fully justified.

The previous speaker raises the question whether, in an old structure, consideration is ever given to the question of the workmanship in that structure. The speaker, for himself, can say that in his practice he does take the workmanship into consideration. How much value can be attached to the better workmanship in an old structure is difficult to arrive at, but certainly some value can safely be allowed; and where the question is as to the amount of load which a structure can be permitted to carry, or whether it should be replaced, and the several factors on either side are nicely balanced, the decision one way or the other may be fairly determined by the quality of the workmanship in the old structure.

The speaker who opened this discussion, together with myself and several others who are here, worked for the Edgemoor Iron Company many years ago. At that time that company was turning out, I think, as high a grade of bridge work as the best shops anywhere, and while that work may not have been so good as is now turned out in the average bridge shop, it certainly was of a high standard for that day, and on that account the speaker has at times given the benefit of the doubt to the continuance in the service, or in permitting increased loading over a structure which he knew had been made at that shop, and which would not have been permitted if it had not been known where the work had been made.

John Brunner, M. W. S. E.: The subject brought up for discussion this evening is of great interest to the structural engineer. It is one that has been thoroughly discussed in the past and one that without doubt will be discussed as long as rolled steel is used for structural work.

Before entering upon the discussion of the assembling and reaming, I want to call attention to the severe treatment which structural steel is necessarily subject to before it is ready for assembling.

We know that the rolled steel when it leaves the finishing pass at the rolling mill is not uniformly cooled throughout the section, principally for the reason that it is not of a uniform thickness. The material is placed on the cooling beds and left there until it has cooled to nearly the same temperature as the surrounding atmosphere. In this process of cooling, some parts of the section cool relatively faster than others, with the result that internal stresses in the material are set up by the unequal contraction. The stresses may vary greatly, depending on the section, and may, under certain conditions, have an intensity close to or above the resistance of the material at the elastic limit. The effect of these high stresses is that the material will bend out of the straight line and must be subsequently straightened either in gag presses or in straightening rolls. In either case, the material will be strained above the elastic limit.

During the loading, transportation to the structural shop, and unloading there, the long or wide pieces are apt to be bent out of shape, due to straining the material beyond the elastic limit in handling it. Some of the material so deformed may have to be again straightened before it is marked for punching and thereby again be strained above the elastic limit. The punching of the material strains it above the breaking point around the punched holes and strains it beyond the elastic limit in other parts of the section, which is shown by the stretching of the material lengthways with the piece and bending sideways. Before the material goes on the assembling skids it has to be again straightened in gag presses, straightening rolls, or by hammering, and thus again be strained above the elastic limit.

The steel is, therefore, at the time it is assembled, full of internal stresses of an intensity close to the elastic limit. Part of these stresses are tension stresses and part are compression stresses, balancing each other. Only a small force is required to disturb this balance, which is shown when full-size tests are made. A permanent set is obtained from the first relatively small load applied, and this set increases in proportion to the load until the elastic limit of the piece as a whole has been reached. The study of the necessary severe treatment of the steel during the process of manufacturing before it enters the finished structure convinced me some years ago that only the softest commercial grades of steel should be used for ordinary structures. In fact, I do not believe it necessary to specify a lower limit for the ultimate strength of structural steel as long as it shows the proper elongation under tensile tests and will stand the usual drift and bending tests. The softer the steel, the better it is, in my opinion, for ordinary structural work, and the better it will stand the necessary severe treatment during manufacturing and erection.

The steel, as mentioned before, stretches in punching, and the stretch increases with the thickness of the material and with the amount of the material punched out as compared with the total cross-sectional area. The component pieces of a member are, therefore, unequally stretched, and in assembling it will be found that the rivet holes do not match. This difficulty is overcome to some extent by using spacing appliances at the punches, which space the holes from the end of the pieces.

The ordinary reaming of the structural material after it is assembled will, therefore, not remove the material concentric to all of the punched holes, and will leave in place some of the material affected by the punching. The only advantage that can be claimed for reaming is that better fit of the rivets should be obtained and that the rivets should better fill the holes after driving.

We made some experiments a few years ago to determine how well rivets would fill unreamed holes. For thicknesses up to three and a half times the diameter of the rivet, we found that the holes

were well filled. Ordinary care was taken in punching and assembling the specimen and the rivets were driven without reaming the holes. The riveted pieces were then carefully cut through the rivet, all burrs removed and the surface polished. The experiments covered thicknesses made up of from two to five plates.

These experiments seemed to indicate that the holes can be well filled by the rivets and good bearing on the rivets obtained up to a thickness of about three and a half rivet diameters, without reaming. Where rivets of greater lengths are used it may be necessary to sub-punch and ream the holes, in order to get good bearing on the rivets. When structural members are made up of several thicknesses, a reamer should be run through all the holes so that the hot rivet can enter the hole quickly and be driven while it is hot, thereby obtaining a well filled rivet hole and good bearing on the rivet.

The principal objection to sub-punching and reaming after the component pieces are assembled, is that burrs are formed around the reamed holes and that chips are sometimes crowded in between the pieces. The burrs and chips, without doubt, greatly reduce the clamping power of the rivets, unless the pieces are taken apart and the burrs chipped off and chips removed before re-assembling and riveting.

Twist drills should be used in reaming in preference to tapered fluted reamers, for the reason that they do not crowd the chips in between the component parts as much as the tapered fluted reamers do. Both in reaming and riveting it is very essential to have the component pieces thoroughly bolted together, in order to obtain tight rivets. Where heavy and thick material is used, it is often necessary to put a bolt in every other hole in order to avoid loose rivets.

I am not assured that it is good practice to use heavy assembling paint. The linseed oil in the paint is, as we know, decomposed by the oxygen it takes from the atmosphere and the paint is thereby caused to dry or harden. The oil in the paint placed between the pieces riveted together does not come in contact with the oxygen, and the paint may, therefore, never dry or harden except where burned by the hot rivets. We are, therefore, in fact lubricating the surfaces which we expect to grip each other through the clamping power of the rivets. As the rivets shrink in cooling they cannot act in bearing until the member has been more or less deformed. It seems from this reasoning that it may be possible to cripple a compression member under a relatively small load if a sufficient lubricant in the form of paint is placed between the surfaces, when the member is assembled, so that the component parts may slide on each other and act independently, when the load is applied, instead of the member acting as one piece.

Heavy members should always be assembled and riveted in a position which causes least deflection from their own weight during

the work of assembling and riveting. Care should also be taken to prevent local overstraining of the finished members in handling and transportation.

President Armstrong: The remark of Mr. Brunner, in regard to painting of surfaces of contact before assembling, is, I think, worthy of further mention. I believe experiments were made some years ago by the American Railway Engineering Association, which tended to show that the strength of a riveted joint depended more largely upon the friction of the parts in contact than the shear or bearing power of the rivets. Now, if that is true, it seems logical that a coat of paint applied between these surfaces would act as a lubricant and tend to decrease the frictional resistance. Furthermore, to develop the full frictional resistance, it is necessary that the several pieces assembled be brought together into intimate contact with each other, and it has often occurred to me that this contact is less perfect with punched work than with work that has been reamed or drilled, for the reason that a punched hole has a burr on one side, which might reduce the effectiveness of the contact. I have never heard of chips getting between the pieces in reaming, as has been mentioned.

I want to speak briefly in regard to the advantage of reaming field connections. Those who have watched erection work have noticed that when holes do not match very well, the erectors insert a drift pin with a long point; perhaps they may be able to get the point through the metal at an angle of about 45°, and then a husky man takes a sledge-hammer and pounds until he forces it through, sometimes elongating the holes until they are about twice as long one way as the other. It seems evident that a great injury is done to the metal by this process, and for that reason I think the reaming, of field connections especially, is very desirable. I do not believe it is always necessary to assemble the pieces in order to get good results. If the connections are reamed to an iron templet, the errors of punching would be practically eliminated.

I do not think there is much question in the minds of engineers regarding the necessity of reaming in thick metal. I think it is almost the universal practice to require reaming in metal ¾ in. thick or more. That question seems to be quite definitely decided. The greatest variation in practice now is in the matter of assembling in the shops. I believe that in most cases a fairly good fit can be made by reaming to templets rather than going to the extra expense of assembling, which expense runs very high in truss work. .

Andrews Allen, M. W. S. E.: There is a great deal to be said on the question of reaming, and I do not believe that it can be settled offhand or by generalizations. . The question should be decided differently under different conditions. In railroad-bridge work, which is, of course, the principal field for reaming, we have, on the one hand, girders and short-span bridges, and on the other hand,

monumental structures like the Brooklyn bridges, the Eads bridge, or the Quebec bridge. In the first case, economy of metal and a high unit stress is comparatively unimportant, since the amount of metal in a bridge does not add greatly to the total load for which it is calculated, while in a very large bridge the economy of metal is of extreme importance. We soon reach a condition in very long spans where a pound of metal added to the structure will require perhaps a half pound of metal to carry it, and the limiting span for a given unit stress will be reached when every pound of metal put into the structure requires a pound of metal to carry it. So we can go on adding metal without making the bridge any stronger. As we approach this limiting span, it is evident that the important considerations are the refinement of workmanship, and the use of special materials, so that the unit stress can be safely increased.

In shorter spans, it is another question altogether, and it seems to me that it is better policy to put more metal in such bridges and get greater stiffness, because the stiffness of the bridge depends on the unit stress on the gross section, not on refinement of workmanship. An unreamed bridge with 5% more metal will be practically 5% stiffer than the same bridge with lighter sections and reamed, and it seems that the logical thing to do is to put in the extra metal—at least to the extent of the cost of reaming—and then not ream. This is especially true in view of the fact, which I think is generally agreed to now, that the injury to metal by punching has been greatly exaggerated. As Mr. Brunner has pointed out, the metal has already gone through a course of athletic training, and any little additional work that it is called upon to do does not hurt it very much.

When we come to monumental structures, Mr. Brunner's remarks also apply. Wherever you punch, whether you ream or not, the metal is stretched beyond its elastic limit, and internal stresses are set up, so if we really want to increase the unit stress and save the metal from injury, the only logical thing is to drill from the solid. Of course, there are practical difficulties in the way of drilling on a large scale, but where it can be handled without too much complication, and the metal clamped in place without difficulty, drilling from the solid actually costs less than punching and reaming. The question of drilling ought to be seriously considered by our shop superintendents, and some method found to accomplish it. It will have to come some day, and will bring with it many advantages in the way of design,—for instance, the use of thicker material.

Many specifications call for an excessive amount of reaming. Even the "Maintenance of Way" specifications require 3/16 in. reaming; that is, 11/16 in. punching for 7/8 in. rivets. This size of hole compels the use of 5/8 in. bolts in assembling. One cannot draw up a big section with 5/8 in. bolts, without putting bolts in about every hole and breaking a good many of them while drawing

up the metal. A bolt 1/16 in. or 1/8 in. larger is a great deal stronger, and assembling is correspondingly facilitated. We ought to ream just enough to be sure that we get a good fit. With careful punching we do not need so much reaming, and we ought to have careful punching. Every process that has another process to follow it up and where the responsibility is divided, leads to carelessness, and I believe in developing processes that are perfect in themselves so far as possible.

Mr. Finley: I will ask Mr. Allen if he thinks the excessive requirements for reaming tend to produce bad or careless punching?

Mr. Allen: I believe that is true, to some extent; also that wherever a process has to be afterwards checked up by another process, it leads to carelessness in the first process. The same thing happens in a drafting room where there is a complete checking system.

In regard to reaming field connections, I agree with President Armstrong that it is important to ream field connections in order to eliminate the chance of misfits. But I believe that we actually get just as good results in most cases by reaming to a steel templet as we do by assembling the connections and reaming them in place, and match-marking. Theoretically, the latter method should produce a better fit in the field, but the pieces are not interchangeable and the time we gain in better fits is lost again by hunting up the member that has the match-mark on it. Reaming to a templet, when a steel templet is used, can be done without difficulty, and accomplishes the same object, at the same time making similar pieces practically interchangeable.

In regard to the question of painting surfaces in contact, the idea seems to be that some water may seep in between the assembled surfaces and start rusting inside the member, but there is little good ground for this belief. If the contact between the members is anywhere near perfect, and if there is a good coat of paint on the outside, well worked into the cracks and spread evenly, I can see no real danger of water penetrating the member, and rust cannot be produced in the absence of water or a supply of oxygen. It stands to reason that the friction between painted surfaces is less than between unpainted ones. Consequently I am inclined to agree with Mr. Brunner, that there is hardly any rational basis for painting the assembled surfaces. Like many things that we do, it is a matter of habit, and some habits—especially bad ones—are very hard to break.

Another matter in this connection. I have recently broken away from the practice of painting steelwork in the shop. A shop coat of paint is put on, as every shop man knows, under very disadvantageous conditions. The painting is the very last thing to be done before the work is shipped out. It is done in any kind of weather, usually in the yard, and by the most unskilled labor. The

work is seldom properly cleaned before painting, and it is frequently injured and scraped during transportation and unloading. Now, if we get rid of the idea, which is pure imagination, that a little coat of rust is going to hurt a structure, then clean it off thoroughly with wire brushes and scrapers in the field and give it a real coat of paint, I believe this will do two things,—first, we will get a really good coat of paint, and second, we will be perfectly sure that the mill scale is all off, for no paint will hold when applied over mill scale. Then, while you are about it, put on two coats of different colors, and pay some real attention to the cleaning and painting, and to the weather conditions while the painting is being done.

S. T. Smetters, M. W. S. E.: Sub-punching and reaming of riveted structural material has been required by specification in such an indefinite way that the requirements are scarcely ever followed. The size of the sub-punched hole may be specified to be 1/8 in., 3/16 in., or 1/4 in. smaller in diameter than the finished reamed hole. Some specifications state that the punch shall be 3/16 in. less in diameter than the nominal diameter of the rivet. At best, specifications are not specific enough; the size of the hole on the punch side or the die side of the material, or the diameter of the punch is specified, but each may allow work which will not be satisfactory, as the material punched with a larger die than necessary will not assemble properly for reaming, and the reaming will not remove all injured or ruptured material from around the hole.

From the following exhibits of punchings (Figs. 1 to 8 inclusive), it can be seen that unless the diameter of the punch and also the die be specified, also the requirement of fair holes,—that is, holes through which a drift pin 1/16 in. smaller in diameter than the punch will drive easily,—it is not a certainty that all the destroyed or ruptured material around the hole, or even the free material, will be removed by reaming. Unfair holes should be reamed at least the amount the holes in the separate pieces of material are out of true and to the required diameter for a rivet. Also 10% of unfair holes should be cause for rejection.

All members of a structure should be inspected after assembling and any unfair holes marked; excess drifting in bringing material together should be cause for rejection.

After the reaming is completed the work should be inspected to detect any poor work, especially at the portion of the member where the rivets will receive a maximum strain.

Figures 1 to 7 inclusive show punchings from material that was specified should be sub-punched and reamed, and that the punch should be 3/16 in. less in diameter than the nominal diameter of the rivet.

Punchings, Figs. 1 and 2, are unsatisfactory, as on account of the large die used the holes will have to be very accurately punched so that they will assemble fairly, in order that the specified amount

of reaming will produce the desired result and that the work will pass inspection.

Punchings, Figs. 3, 4 and 5, will produce good work if the holes are fair.

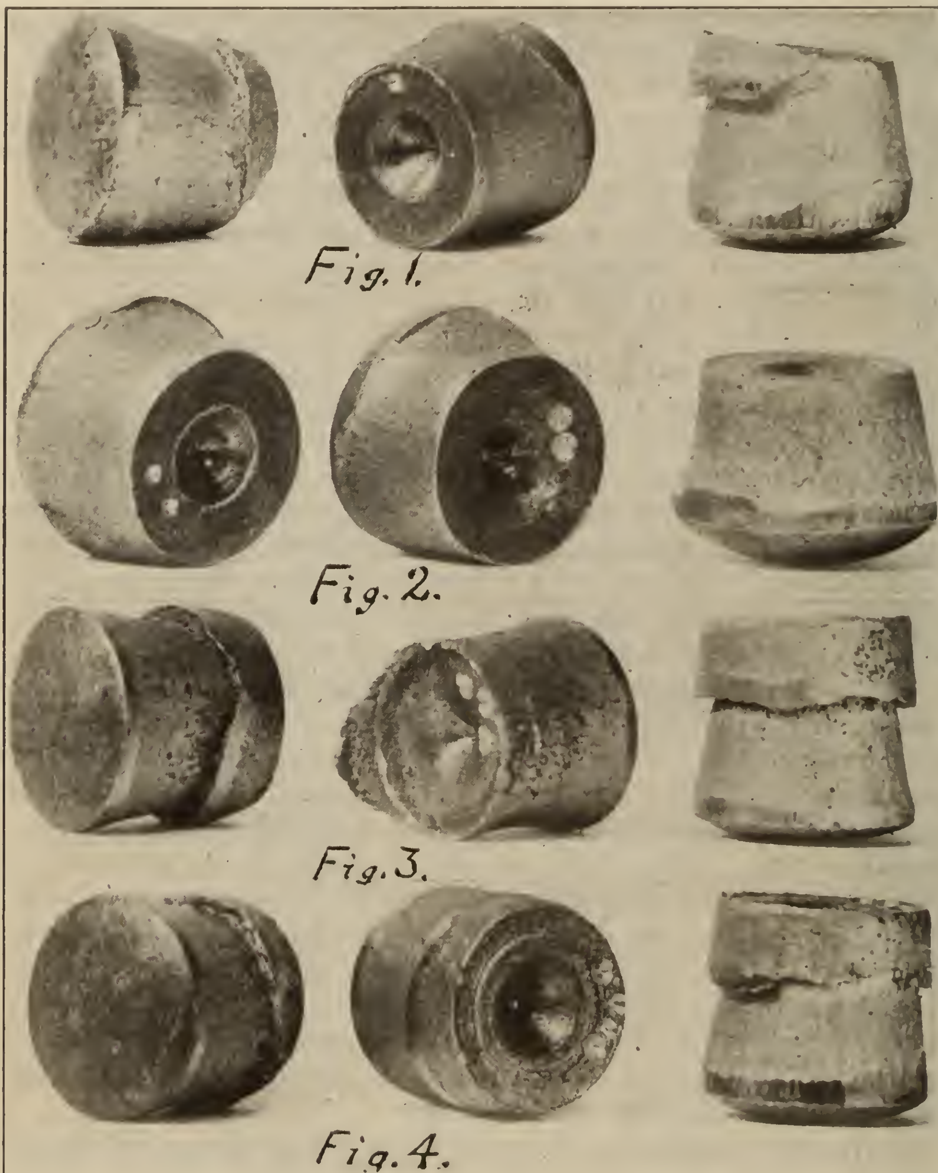


Fig. 1. Punch $\frac{11}{16}$ in.. Diam., Die $\frac{23}{32}$ in. Diam
Fig. 2. Punch $\frac{11}{16}$ in. Diam., Die $\frac{29}{32}$ in. Diam.
Figs. 3, 4 and 5. Punch $\frac{11}{16}$ in. Diam., Die $\frac{3}{4}$ in. Diam.

Punchings, Fig. 6, show lack of care in setting the punch in the machine, the punch and die not being concentric.

Punchings, Fig. 7, multiple punch, spacing table work, shows good work, and the holes from which these punchings came were smooth throughout.

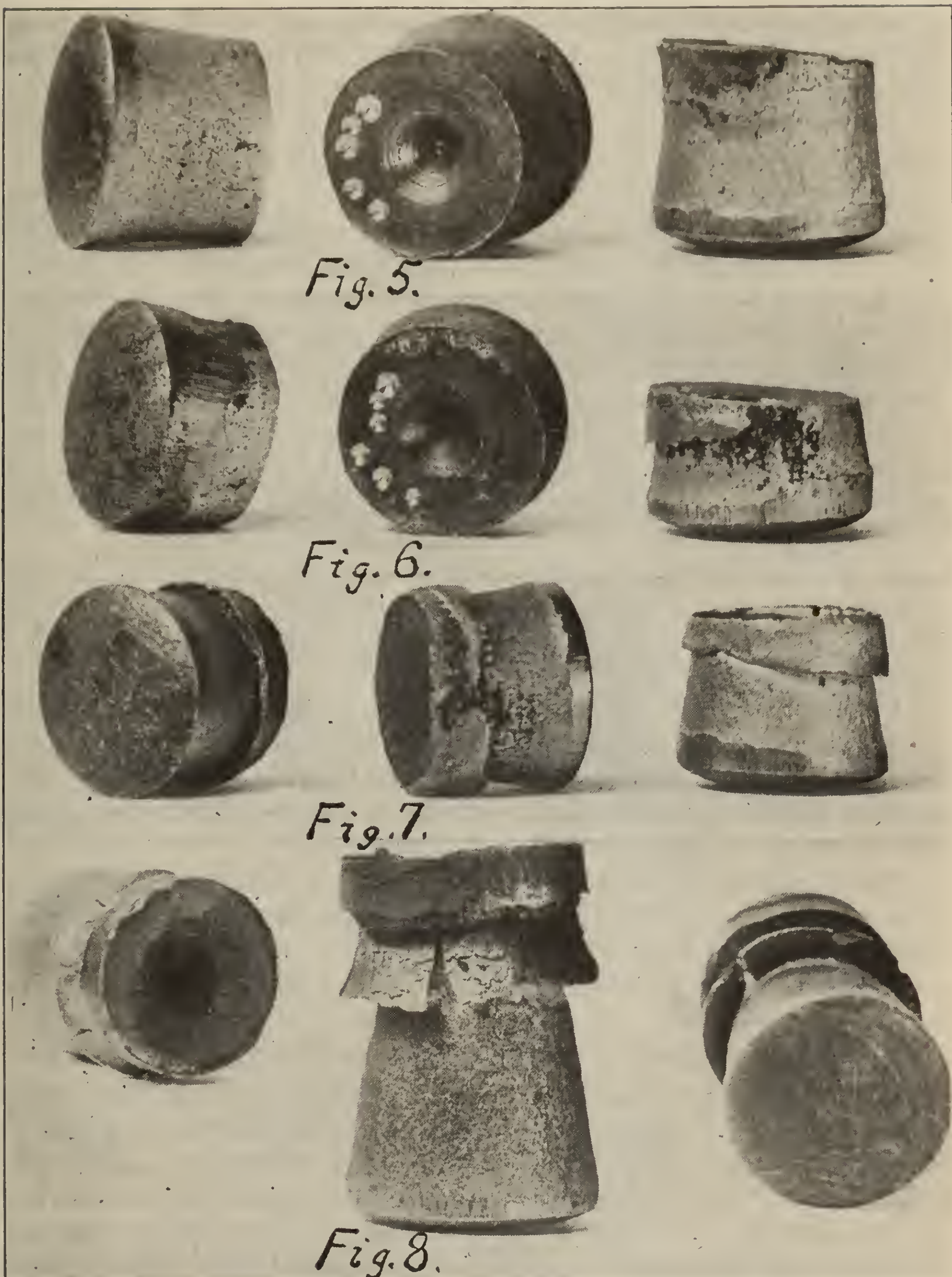


Fig. 6. Punch Off Center, Machine Guides Not Lined Up.
Fig. 7. Punch $\frac{11}{16}$ in. Diam., Die ¾ in. Diam. Good Centering, ¾ in. Material.
Fig. 8. Punch $\frac{13}{16}$ in. Diam., Die ⅞ in. Diam. Material 1⅛ in. Thick. Bethlehem Beam.

The minimum difference in size of the punch and die, with which the punch will stand up under the work, will vary according to the thickness and hardness of the material and speed of the punch.

For punchings, Figs. 1 to 6 inclusive, the machine had a speed of from 55 to 60 strokes per minute.

For punching, Fig. 7, the machine had a speed of 18 to 20 strokes per minute.

For punching, Fig. 8 (three views), the machine had a speed of 34 strokes per minute. The punch was Allen chrome-vanadium steel. The hole from which this punching came was smooth. It will be noted that the first rupture lies inside of the die shearing, and considerably inside of the punch. As the punch passed through this ruptured material, note how it cleared out the metal which forms the collars around the punching which was between the first rupture and the finished hole. The collars on the punching seem to indicate that there might have been a compound rupture at first which was caused to stand out from the surface of the punching, due to the drawing out of the body of the punching.

It will be noted that the funnel-shaped recess which is 5/16 in. deep (not due to the mark from punch), was caused by the drawing out of the body of the punching. This recess can also be noted on punchings, Fig. 3.

In conclusion, it can be stated that punches 11/16 in. diameter will punch material, ordinary structural steel, up to 1¼ in. in thickness, at a speed of 35 strokes per minute, and stand up well under the work, and that it will not be necessary to have the die more than 1/16 in. larger in diameter than the punch.

The guide head of the machine should be rigid to get the best service from the punch, and the machine should have sufficient capacity.

The oiling of punches does not seem to be of any particular advantage.

The machine should be in first class condition to get good work.

President Armstrong: I wish to refer to two of the sample punchings. One I understand left a clean, smooth hole, while the other left a ragged hole. The thought suggests itself that possibly in the case of the apparently smooth hole, metal may have been loosened during the punching and so crowded into the space along the hole when the punch went through as to appear smooth, while as a matter of fact it was surrounded by fibrous, loose metal.

Eugene A. Balsley, ASSOC. W. S. E.: Does not the fact that one punching was smooth indicate that the material punched was thinner than that in which the punching showed a collar? Several years ago I experimented with some heavy material, 1 in. thick, and got exactly such punchings as exhibited by Mr. Smetters, with a collar around them near the punch side. I took the punched plate and sawed it in two through the hole and pulled out two semi-

circles of steel, which indicated that the loose metal was forced into the plate. From the fact that the loose metal is pushed into the outside of the hole, forming a circle or ring, it tends to stay there; whereas, in thin metal there is not so great a resistance in punching; consequently, the pressure exerted is not great enough to hold the loose metal in place.

James Lister: One thing which I would like to have discussed here this evening is how much to ream. As Mr. Allen said, some of the specifications call for reaming, the material to be sub-punched 11/16 in., and reamed to 15/16 in. Other specifications call for material to be sub-punched 13/16 in. and reamed to 15/16 in.

Mr. Finley: Mr. Lister has had considerable experience in the shop and in investigations on other lines. I would ask him if he ever found any such condition as Mr. Brunner discovered in reaming,—the chips getting between the members?

Mr. Lister: No, I did not. When I worked for Mr. Lassig we experimented along those lines. Now, you know that when Mr. Lassig managed the shop we turned out good work. Why? Because he got good prices, and there was no trouble in the field. There was no reaming of field connections, it was never heard of, and the only spans that were put together were the lattice spans. Of course, the way the shop does it now—I am a shop superintendent myself—is to get out that punched work and get it out quickly.

F. E. Davidson, M. W. S. E.: I would ask Mr. Lister for his personal opinion upon the variation in specifications; that is, as to 11/16 in. punching and 15/16 in. reaming as compared with 13/16 in. punching and 15/16 in. reaming.

Mr. Lister: According to my judgment, I would sub-punch 11/16 in. and ream to 15/16 in. on pin-connected spans and lattice work, and on girder spans I would sub-punch 13/16 in. and ream to 15/16 in.

Mr. Davidson: So far this evening our discussion has been largely confined to railroad work. There is a gentleman present who has had a great deal of experience in the design of building work. When we compare the total steel in building construction with the total steel used in bridge construction, I think we will find the preponderance favors the building construction. I would like to hear from Mr. J. H. Heuser as to reaming of structural work for buildings.

J. H. Heuser, M. W. S. E.: We do not specify much reaming in building work; we make this specification only when the metal gets above ⅝ in. thickness.

I have noticed, from the standpoint of selling steel,—I sold steel for several years,—whenever specifications called for reaming of ⅝ in. and over, very little attention was paid to it in figuring the work, as it was assumed in most cases that the specification

could be avoided in the fabrication of the work and the work simply punched. In one instance we specified that metal over ⅝ in. in thickness should be sub-punched and reamed and we insisted rigidly on that specification. The shop was very much annoyed over this specification, but they did the work. They rigged up a special reamer and advertised the giant reamer afterwards as part of their equipment.

There is a question in building work to which I think more attention should be paid, and that is painting. I think that is as essential as reaming. The specifications as often written call for 33 lb. of red lead to the gallon of oil,—a practically impossible specification and seldom lived up to. There should be some way of getting an honest coat of paint in the field.

H. W. Rutherford, ASSOC. W. S. E.: Speaking of reaming to 15/16 in. from ⅝ in. holes through ⅞ in. metal, it may be possible that this will work all right for awhile. One may punch ten holes and he may punch fifty, before the punch will fail. The amount of shear is large and as a general rule it is customary to make the punches too hard and then they will break. I do not quite see the necessity of so much reaming.

In regard to drift pins in field work. To drill holes will not eliminate that cost. If one hole of a series is out of line or does not match up, the whole connection is generally affected. This bad matching of field-work holes is due perhaps to the wrong "center to center" distance. In heavy girder work where there are ¾ in. angles with ⅞ in. punched holes in both legs, as they are for cover plates, the angle is generally bent both ways; that throws the holes out to some extent and drift-pin work cannot always be avoided.

With reference to painting two surfaces before they are assembled; anybody who is familiar with this work or has anything to do with the shop, knows that these surfaces become hot from the hot rivets. There is a question how much paint there is in there after the riveting has been done.

All reamed work has the burr on the outside. Years ago, in the best work, these reamed holes in girders were all countersunk a very small amount, say 1/64 in. A man went around with a hand reamer or something of that sort and took off the burr on both sides, which made the rivet slightly countersunk, and secured a much better piece of work.

John G. Kreer, M. W. S. E.: We find no trouble in punching heavy material, provided the punches are hard and clean, the die not too large, and the head of the machine very well stiffened, so as to give thoroughly rigid running of the punch. We are able to successfully punch 1⅛ in. material with 13/16 in. holes apparently clean, the sides approximately parallel and very smooth. There may be a ring of metal inside but I have never had occasion to investigate that. At any rate, the metal which takes the bearing of the rivet is smooth and clean.

Our experience also confirms Mr. Smetters' statement that the cost of drilling from the solid is not far from the cost of sub-punching and reaming. I think, with a little change of shop equipment, we would as soon drill from the solid as sub-punch and ream in heavy work, running into ⅞ in. and 1⅛ in. material. The sub-punching is quite a serious item because of breaking punches and the loss of time in replacing them, setting the machine and getting adjustments in order.

The specification of 3/16 in. of metal to be reamed out in metal of ⅞ in. thickness, makes a very small hole to be punched; there we find an ordinary punch will not average more than 15 to 20 holes before breaking. By using vanadium-steel punches, we get somewhat better results, and the punches last enough longer to far more than offset the added cost of such special steel.

Mr. Heuser: No doubt there are a number of members present who at times have had occasion to saw rivets in two, or to similarly saw a section of riveted metal, and have examined carefully the condition, or apparent condition, of the metal around the rivet. I would like to hear from them, what the appearance of the metal was, as near as they can describe it.

Mr. Davidson: I remember reading a specification for a little job of steel when I was connected with the North Works, Illinois Steel Company. It was for some work that the Government was erecting near Milwaukee, for the lighthouse commission. I believe in that specification everything had to be planed, and I remember distinctly that every piece of steel had to be given a sand blast before it was punched. I never forgot that specification.

Mr. Smetters: In regard to reaming, the engineers who specify sub-punching and reaming presumably pay for it, or some one pays for it; but it is a question in my mind as to whether many of them get it. The inspectors may go into the shop and inspect the work *after* it is fabricated complete. They determine whether or not the field connections are reamed. The other connections may or may not be reamed, and if, as Mr. Finley says, the holes are punched ⅛ in. out of their proper position,—one may be ⅛ in. one way and another ⅛ in. the other way,—you get one round hole where the reamer starts, and then a series of slotted holes. That is the condition that will exist, even though it may not be a general condition. If there is a mismatched hole and a man sees that in the shop, he is going to cover it up if he can. Almost without exception, the inspection is very poor in the assembling shops. I believe, though, the tendency now is toward much better punching than has been the case in the past.

I agree with Mr. Brunner that there is a great deal of trouble from chips getting between the members of a structure where it is reamed through several thicknesses. For instance, all material, after it is punched is crooked more or less, and unless a bolt is

put in every hole, making it impossible to ream, it is practically impossible to get the different thicknesses of the metal in contact. The result is one may pull it together with the bolt, but as soon as he takes the bolt out that metal has a permanent set, which is too great to be pulled out by a bolt; it springs back, and the result is that chips get between the two thicknesses of the metal. This is especially true in using the tapered, fluted reamer. There is not so much difficulty with the twist drill.

On portions of the Butterfly Dam, of the Sanitary District of Chicago, the work was drilled in the solid. There were five thicknesses of 7/8 in. plate. The drilling was done with a high-speed drill, and as fast as drilled the holes were bolted up solid. One-inch rivets were used, and no trouble developed with chips getting in between the plates. Those plates were of maximum size, 11 ft. by 12 ft., by 7/8 in. thick. As I recall now, a hole in a little over 5 in. of metal was drilled in less than three minutes. On the eight-track bridge there were about five thicknesses of metal, and it was very quick work to drill them. It was found that at a lower speed the drills worked more freely, but there was no trouble because of the chips getting in between the plates. I remember that very distinctly.

Mr. Davidson: If I am not mistaken, some years ago the North Works of the Illinois Steel Company made a series of tests upon the frictional resistance of two 3/8 in. plates, 3 in. wide, with one 3/4 in. hot-driven rivet in single shear, as compared to the bearing and shearing value of the same rivet. Am I not correct, Mr. Brunner, in the statement that the frictional resistance between the 3/8 in. plates was slightly more than the allowable bearing value on the 3/8 in. plate or the shearing value of the 3/4 in. rivet.

Mr. Brunner: I do not remember the details of the experiment or the results we obtained, and cannot at this time verify Mr. Davidson's statement. We made a large number of tests on riveted joints at that time, which were placed on record in the publications of the American Railway Engineering and Maintenance of Way Association.

Mr. Davidson: As I recall the experiment, the result was that the friction resistance of the two 3/8 in. plates was somewhat greater than the ordinary bearing or shearing value permitted by engineering practice for a 3/4 in. rivet. There has always been a question in my mind as to the necessity of the expense of punching and reaming except on railroad work, where every pound of steel actually counts. On structural work, I do not think it is necessary, required, or customary; at least, I have never specified it in my work. I have always felt, basing my opinion on those experiments, that the only effect the rivet had was to give frictional resistance between the plates.

G. W. Niestadt (Vierling Steel Works): Concerning the

frictional resistance between riveted plates, let me relate a little experience I had some years since, inspecting an old bridge structure, which was to be repaired. The engineers of the railroad company informed me that no loose rivets could be found in the structure, but I found enough of them, I assure you.

It appears to me that if we depend upon frictional resistance, if there are any loose rivets in the structure there will be no resistance of any value.

I would like to hear from somebody on the question of why we specify reamed holes in structural steel work for buildings, especially reamed holes in columns. The question arises nearly every day in our business, and when it is brought up to the engineer, in nine cases out of ten he will say, "Well, I copied those specifications from another set and I do not think that the question of reaming applies to this job in particular."

In many instances we receive specifications where the engineer, or architect, is not very well acquainted with structural steel work. To ease up his work, he has taken a text-book, allowed his stenographer to copy the specifications from that book, and let it apply on his job. He will call for estimates and when he receives them finds there are two or three low ones, and the balance, or the majority, are high. Then he wonders why he receives so many high figures and so few low ones. The low bidders are probably assuming that he has copied the specifications. They are playing on the possibility, that after the job is let he will forget about the reaming.

Mr. Lister: I would like to ask Mr. Niestadt why his company reams work at its shop when reaming is not specified?

Mr. Niestadt: We pass a reamer through all holes to facilitate the work in riveting.

Mr. Horton: Twenty years or more ago Hoopes & Townsend, of Philadelphia, manufacturers of blank nuts, distributed nickel-plated paper weights in the shape of a nut 2¼ in. thick, cold punched with ⅜ in. punch. The pressure would have been at least 150,000 lb. if punched as in the usual practice, 40 strokes per minute. This pressure on the area of the punch would have represented 1,350,000 lb. per sq. in., while the punch itself could only stand approximately one-twentieth of the 150,000 lb., that is, 7,500 lb. It is my understanding that the work was accomplished in an hydraulic press with an accumulator maintaining a uniform load of 7,500 lb. pressure on the punch, and in due time the punch found its way through the 2¼ in. metal; clearly developing the fact that wrought metal will flow.

Mr. Smetters tells us that one shop had difficulty in punching 11/16 in. holes through 1⅛ in. material. To punch an 11/16 in. hole through 1⅛ in. metal, running 40 strokes per minute, will require more than 100,000 lb. pressure on the punch. If so, the pressure would be 370,000 lb. per sq. in. of the area of the punch.

With any such pressure it is apparent that the slower the punch runs (giving the metal time to flow) the better results may be expected. Mr. Smetters also stated that the multiple punch worked best. The multiple punch runs 20 strokes per minute, the other punches running essentially twice as fast.

In these days we have come to hear much of "intensified" agriculture, the term, I believe, meaning human-brain force assisting nature in bringing forth abundant increase. How marked the success has been or is to be may be set aside at this time as a mooted question as far as agriculture is concerned. We have with us intensified engineering, and I am inclined to say that the class of design Mr. Smetters refers to may be considered as an example.

To illustrate: A rolling girder in such a structure weighed approximately 60 tons.

The engineer estimates the cost as follows:

Material delivered at the bridge shop	$30.00 per ton.
Manufacturing	15.00 per ton.
Overhead	5.00 per ton.
Total	$50.00 per ton.

The intensified designer discovers that a rolling lift girder on this basis costs $3,000.00.

The manufacturer sees the distribution of cost something like this:

60 tons of material	$30.00 per ton.
Manufacturing	50.00 per ton.
Overhead	5.00 per ton.
Total	$85.00 per ton.

Sixty tons at $85.00 per ton equals $5,100.00.

The manufacturer's cost is $2,100.00 in excess of the designer's estimate,—that is, 70%,—for one such girder. This represents the difference between the intensified designer's ideas of the cost of this so-called structural girder and the manufacturer's knowledge of what it costs. This is workmanship to the nth degree.

If built strictly as structural work, the girder would cost no more but would have required 100 tons of material. There would not have been the chance for the display of intensified brain work, but I have every reason to conclude it would have been a more useful design. It surely would have required less counter-weight for the structure.

Lest there be a misapprehension as to my views of the proper way to handle structural steel, I wish to say that I fully believe if the material is so hard when punched that one invariably hears an explosion, it is better to ream it, or, still better, to drill it.

In my experience I have had some very hard material to form into buckle plates for a bridge floor, working the plates cold.

After several had failed by cracking, it was suggested that we plane the edges and observe the results. I am pleased to report that after planing the four edges of those plates, not one failed out of several hundred. The material in those plates was excessively hard and the planing of the edges relieved a very awkward and uncomfortable situation. The conclusion is, never allow yourself to have such excessively hard material; or, if circumstances are beyond your control and force it on you, machine-cut it; that is, plane or drill in preference to attempting to shear or punch.

Mr. Balsley: In regard to the question of incipient fracture in punched work, some years ago we had a girder sent to us from the Illinois Central Railroad, which had come in contact with a locomotive, and that girder was folded back on itself something

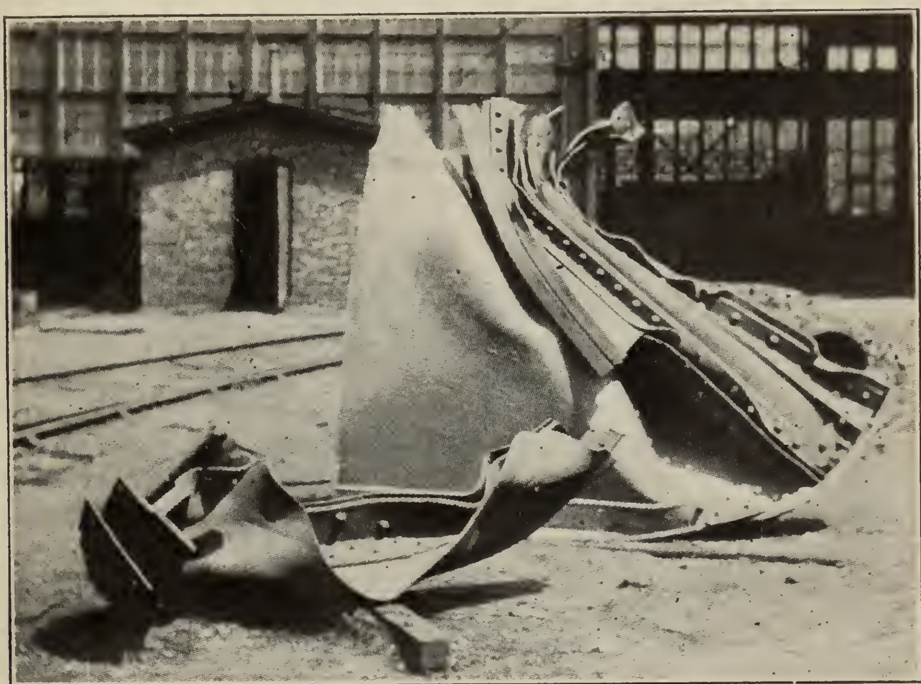


Fig. 9. Plate Girder, Folded—Rivets Sheared Off, but Web Not Fractured.

like an accordion plait. There were six folds and the width of the girder, out to out of folds, was only about 3½ ft.; that is, the folds were that close together. It was fabricated at the same plant where it was returned to be repaired and was plain punched work, not reamed. There were 126 rivets sheared off completely and pulled out of the holes; yet there was not a single sign of fracture in any rivet hole, with the exception of this so-called incipient fracture due to the punching. The web of this girder (which was a round-end girder) was torn straight through about 3 ft. at the center of the girder. (See Fig. 9). In this case, the fact that the work was punched and not reamed does not seem to show that any particular harm was done to the structure.

Mr. Finley: There is no doubt that fifteen years ago, when we started in with the use of steel, we settled the question of reaming, as Mr. Loweth has said. I think, however, that it is again open for discussion, and that we are going to modify our views somewhat.

I was interested in what Mr. Brunner said regarding the chips from the reamer getting in between the pieces, and also much surprised that Mr. Lister had never discovered this. I have found this condition on several occasions. When it comes to a question of accuracy of the work for erection in the field, I think that the necessity of a drift pin to draw it up depends largely upon the skill, or lack of skill, of the erector. Can one "slam" a bridge together in many ways. The possible damage to a punched hole and the consequent trouble that may develop, is a question. As I said earlier in the evening, I have taken down a great many old bridges, and that was one of the least of our troubles.

I am glad that Mr. Loweth has the assurance to continue a bridge one year more on account of the shop work. I have never gone that far.

The reason I raised this question is because I believe the manufacturer is largely in the hands of the engineer. I believe he will carry out what the engineer requires just as far as he can. Frequently he matches wits with the engineer, and when he does he generally comes out ahead.

Speaking of smooth holes, I remember an inspector telling me what nice smooth holes he had found, absolutely accurate, but when they came to put the work up in the field, the hot rivet caused the *lead bushing* to drop out.

I would like to see the shops encouraged to do accurate punching and accurate laying off. The fundamental part should be done just as well as possible. I believe that any bridge that is properly designed and the holes punched will never fail for lack of reaming.

Referring to experiments that were made on riveted plates to determine the frictional resistance of the plates, if any of the members present will look back over the literature of bridge building they will doubtless find that such experiments have been made many times. I remember twenty-five years ago seeing an experiment where the middle plate contained a slotted hole, and it has been made a number of times since. There is no question of frictional resistance existing just after the riveting has been done, but I do not believe it would be safe to rely upon it or count upon it for any length of time, because in a railroad bridge enduring shock and vibration the frictional grip would be very apt to be destroyed, and I earnestly advise putting in the necessary number of rivets rather than depend upon frictional resistance.

IN MEMORIAM.

WILLIAM H. HARRIS, M. W. S. E.,

Died January 31, 1912.

William H. Harris, estimator of the John M. Ewen Company, passed away January 31, 1912, after an illness of three and one-half months. Mr. Harris suffered from a nervous breakdown October 13, 1911, and failed rapidly. He was born in Goshen, New York, June 3, 1879. Most of his life was spent in New York City, where he obtained his knowledge of the building business. He came to Chicago in 1901 and began work with the George A. Fuller Company, under Mr. Merriman. In 1905 he resigned his position with that company to accept a position with the John M. Ewen Company, with which firm he remained until his death.

During the several years Mr. Harris was connected with the Ewen company he proved himself to be exceptionally competent and faithful in the duties which were allotted to him incident to his position as head of the Estimating Department. He exercised the greatest possible care with all of his work in its utmost detail, not only in connection with his own special work, but it was his ambition to learn as much as possible of all the different branches of the building business, with a view of fitting himself for whatever larger position might be open to him in the future. He was very considerate of all those with whom he was associated in business, and had the art of breaking the news to the unsuccessful bidder in such a manner that the bidder was not disgruntled but was always willing and glad to figure on any other work when invited to do so. Mr. Harris proved himself to be a man of unusual ability and of great promise, which he demonstrated in his work in connection with the contract for the Plymouth Building, Minneapolis.

Great credit is due Mr. Harris on account of the success that he achieved and his ambitions for the future, because he was essentially a self-made man. His parents having died during his infancy, it became necessary for him to go to work and make his own living at the age of eleven years. He is survived by his wife and two sons.

Mr. Harris became an Active Member of the Western Society of Engineers in December, 1906.

John M. Ewen.

May, 1912

PROCEEDINGS OF THE SOCIETY.

MINUTES OF THE MEETINGS.

Correction.

The minutes of the regular meeting of April 1st are incomplete as printed in the *Journal* for April, 1912, Vol. XVII, page 379. The following was omitted:

The Board of Direction, at their meeting of March 29, received applications for membership in the Society from the following:

Gunni Jeppesen, Chicago.
Lester E. Voss, Chicago.
Theodor Rall, Chicago.
Frank W. Kottke, Chicago.
Walter Y. Shaw, Chicago.
Meyer J. Sturm, Chicago.
David M. Wright, Chicago.
Ray Palmer, Chicago.

Also at that same meeting the Board of Direction elected into membership the following:

G. A. Caproni, Salt Lake City, Utah............Associate Member
Robert C. Schwartz, Chicago, transferred to.....Associate Member
James S. Harvey, Jr., Chicago.................Junior Member
James Sorenson, Chicago.......................Student Member
A. B. Whitney, Chicago, transferred to..........Associate Member
Sidney J. Robison, Chicago.....................Associate Member
F. W. Greve, Jr., Lafayette, Ind................Associate Member
Floyd E. Downing, Chicago....................Member
George M. A. Ilg, Chicago, transferred to.......Associate Member
Frank H. Masters, Chicago....................Member

Extra Meeting, April 22, 1912.

An extra meeting (No. 784), being a Joint Meeting of the Electrical Section, W. S. E., and the Chicago Chapter, A. I. E. E., was held Monday evening, April 22, 1912.

The meeting was called to order at 8:25 p. m., Prof. P. B. Woodworth presiding, and about 30 members and guests in attendance. There was no business to be considered. The chairman introduced Mr. Burke Smith, of the Engineering Department of the Chicago Telephone Co., who read his paper on "Depreciation and Replacement of Growing Telephone Plants."

Discussion followed from the chairman, and Messrs. A. H. Hyatt, S. R. Edwards (Telephony), R. V. Achatz, G. T. Seely, R. H. Rice, A. Bement, W. J. Miskella and Donald Bowman, with replies from Mr. Smith.

A vote of thanks was tendered Mr. Smith for his address.

The meeting adjourned at 9:45 p. m.

Regular Meeting, May 6, 1912.

A regular meeting of the Society (No. 785) was held Monday evening, May 6, 1912.

The meeting was called to order at 8:20 p. m., President Armstrong presiding, with about 35 members and guests in attendance.

The minutes of the last regular meeting of the Society were read and approved.

The Secretary reported from the Board of Direction the following list of applicants for membership.

Ray Seely, Hammond, Ind.
James Sinclair Pole, Chicago.
Frank H. Cenfield, Chicago, transfer.
Raymond D. Anderson, Fond du Lac, Wis.
Sidney T. Corey, Chicago.
Ralph M. Yager, Chicago.
William B. Poland, Manila, P. I.
R. P. V. Marquardsen, Chicago.
James A. Dyer, Gillespie, Ill.
Robert J. Smith, Chicago, transfer.
Charles W. H. McKercher, Camagüey, Cuba.
James R. Scott, Jr., Denver, Colo., transfer.
LaVerne J. Ruddock, Wheaton, Ill.
Laurits W. Skov, Chicago.
Max W. King, Madison, Wis.
Benjamin Nelson, Chicago.
Roy W. Flowers, Chicago.

Also that the following had been elected into membership:

Gunni Jeppesen, Chicago........................Member
Frank W. Kottke, Chicago......................Junior Member
Ray Palmer, Chicago..........................Member
Theodor Rall, Chicago.........................Associate Member
Walter Y. Shaw, La Grange, Ill................Associate Member
Meyer J. Sturm, Chicago......................Member
Lester E. Voss, Chicago......................Associate Member
William A. Webb, Gary, Ind...................Associate Member

There being no other business, the President introduced Mr. E. L. Lundgren, late Project Engineer for the Board of Public Works of the Philippine Islands, who gave an interesting "Talk on the Philippines" which was illustrated by a number of stereopticon views. Discussion followed from Messrs. R. F. Schuchardt, W. C. Armstrong, H. B. Kirkland, F. J. Munoz, with replies and a closure from Mr. Lundgren.

On motion of Mr. Roper a vote of thanks was tendered Mr. Lundgren for his interesting address.

Adjournment at 10 p. m.

Extra Meeting, May 13, 1912.

An extra meeting of the Society (No. 786) was held Monday evening, May 13, 1912, and was called to order at 8:20 p. m.

This was a social meeting—a "Ladies' Night"—with President Armstrong presiding and about 75 members and guests present, including ladies.

Mr. W. R. Patterson, M. W. S. E., gave an informal picture talk, "A Trip Around and About the United States," illustrated by a large number of stereopticon views.

Refreshments were served afterwards. The meeting adjourned about 10 p. m.

J. H. Warder, Secretary.

BOOK REVIEWS.

Valuation of Public Utility Properties By Henry Floy. McGraw-Hill Book Co., New York. 1912. Cloth, 6 by 9 in.; pp. 390, including index. Price, $5.00.

As the present is a time of official chaos in the manner of expressing and ascertaining public utility values, it would hardly be fair to speak of "Valuation of Public Utility Properties" as wholly disappointing.

As this book is an impartial bringing together of things good and bad, in the way of public utility valuation, there will be no disappointment in the expectation that much of the best work which has been done in this field of human endeavor will be found within its covers.

If, however, any relief is expected from present conditions, or if it is expected to find any manifestation of an adequate effort to perform the first duty of an author, the separation of the good from the bad, in such manner as to make them distinguishable, there will be disappointment, for one searches the 390 pages in vain for any indication of order evolving out of chaos.

A mere compilation, in a fragmentary way, of what has been said and done by courts, public utility commissions and individuals, relative to this subject, is of little worth, if there is no elimination of conflicting theories and doctrines of valuation; no separation of the fallacious and inadequate from the sound and sufficient.

The author adopts the word "tangible" to distinguish those elements of value which grow out of market fluctuations of commodity prices; and "intangible" to characterize elements having their birth in the activities of the utilities themselves. This is done with apparent unconsciousness of the fact that fluctuations of market prices are the most evanescent and intangible forces which operate to produce changes of value; while, on the other hand, those elements which are the result of the service rendered by the utility, which spring from its business activities, when properly understood, are the only ones which possess any of the attributes of tangibility.

The application of the term "development expenses" to those promotion and preliminary expenses which always occur during the construction of a plant, and which are really a part of the cost of its construction; also the application of the term "going value" to the real development expenses, that is, the cost incurred in building up the business, after the construction of a plant, cannot be too strongly deprecated.

Such a use of terms serves only to add to and perpetuate erroneous conceptions of the fundamental elements and facts underlying public utility values.

The conception of "going value," which makes it the equivalent of the expense of transforming the plant from a dead to a live income-producing property, or that measures it by the losses sustained in building up the business of the plant, is apparently more satisfying to the author than a conception which rests in the economic value of the business after its production. That is, what is usually and properly classed "development expense," seems to him a truer measure of value than the actual increment of value created. In other words, the cost of producing a given revenue, which revenue can be concretely expressed in dollars, is a better measure of value than the dollars themselves.

What the author says regarding the subject of depreciation, that "there is today probably no subject requiring more illumination and coordination by the engineering profession," and that the demands of commissions, legislatures and courts for a proper treatment of the subject "has resulted in a divergence of thought and lack of uniformity of practice that is bewildering," is doubly true with regard to these other and more important factors, which enter into public utility valuations, if the evidence furnished by this book is accepted. B. W.

Who's Who in Science (International), 1912. Edited by H. H. Stephenson. New York: The Macmillan Co. 335 pages, 5½ by 9 in. Cloth bound. Price, $2.00.

This book purports to be a list of living men in science, but as in the nature of a first book of this kind, is not complete. In looking over the names one may find some acquaintances among many never heard of before, and a further search may not show some names that were

looked for. Another and later edition will give the compiler an opportunity to correct this. A classified index at the end of the volume shows the different departments of science which have been selected as: Astronomy and Meteorology, Botany, Chemistry (pure and applied), Engineering, Geology and Mineralogy, Mathematics (pure and applied), Medicine and Surgery, Physics, Zoölogy. Under these several heads the list of names are classed under the name of the country where the individual belongs, arranged alphabetically. But the main body of the book consists of the names of scientists, so arranged that any one name looked for, can be readily found if herein. This is followed by a brief statement pertaining to date of his birth, standing, position, address, and his contributions to scientific literature. In the beginning of the book are two pages of abbreviations employed. Following this a list of the world's universities, giving location, date of founding, principal, registrar, and senior professors. This also gives a fair index as to the character of the institution and the courses of study most favored. As would be expected, the greatest number of names are of Englishmen, but nearly 100 Americans are listed.

PREVENTION OF RAILROAD ACCIDENTS OR SAFETY IN RAILROADING. By George Bradshaw. The Norman W. Henley Publishing Co., New York, 1912. 4½ by 6½ in., 173 pages, 22 illustrations in the text, stiff paper cover. Price, 50 cents.

The first portion of this admirable little book is a "heart to heart" talk with railroad men as to their duties to themselves, their fellow workmen, and the railroad company; what to do, or not to do, to lessen the risk of accidents.

The author was in the employ of the N. Y. C. & H. R. R. R. for several years, engaged in the special service of investigating accidents and in formulating rules to lessen them. This applied to shop and roundhouse work as well as on the road.

Many of the illustrations are of conditions about stations and along the tracks, which might easily lead to serious accidents to the public and also to the employees of the road. The management of the railroad are looking after these matters and have formulated rules governing such matters, which rules are added to from time to time as necessary to lessen the risks of accidents, but the author in his addresses to the employees of the railroad, at different times and places, shows them that the fault is with them—that they do not follow the rules and use common sense—with the result of accidents to themselves or a fellow workman. A better understanding of their duties has been shown in their voluntary attendance at the meetings which the author held with the railroad employees, their keen personal interest in the subject, and their appreciation of the practical, helpful suggestions. Employees, it is reported, have tendered voluntarily their appreciation of the information conveyed in these discourses, and have shown that they have been impressed with the facts as set forth and of their intimate relation to them. Also of their serious obligations in the matter, and have caused them to be more thoughtful and careful to so conduct themselves to greatly lessen the risks of accident.

We may hope that this good work will go on and that the lives of railroad men may be prolonged and with continual decrease of risk of personal injury.

THE ECONOMICS OF CONTRACTING. A Treatise for Contractors, Engineers, Superintendents and Foremen Engaged in Engineering-Contracting Work. By Daniel J. Hauer. Published by E. H. Baumgartner, Chicago, Ill. Cloth; 6 by 9 in.; pp. 271. Price, $2.50.

Young engineers today are turning toward contracting work as a means of utilizing their technical education, and ready writers are sup-

plying printed matter to meet a demand for information. Much of this literature (?) is of the potboiling kind, but a few really well-informed men are doing good work. The author of the book under review is an engineer and contractor of fully 25 years' experience. For a number of years he was a contributor to "The Dirt Mover" and then became the editor, joining the editorial staff of "Engineering-Contracting" when that paper absorbed "The Dirt Mover." He was prominent in the organization of the American Society of Engineering Contractors, and served as secretary for two years. He had to resign this position to give the necessary attention to his growing practice as an adviser to contractors, being perhaps the first consulting contractor and the founder of a new profession. Shortly after quitting editorial work with "Engineering-Contracting," he became the eastern editor for "The Contractor," which position he still holds and at the same time attends to his contracting work; eating and sleeping hours being considered an annoying waste of time by this type of man.

A biographical sketch of an author is often the best sort of a review of his book. The book is reviewed when his life is reviewed. Mr. Hauer has performed a real service for young engineers as well as for contractors, in writing "The Economics of Contracting." In ten chapters he discusses: Contracting as a Profession; Forms of Contracts; Proposals, Bonds, Arbitration and Other Features of Contracts; The Business End of Contracting; The Clerical End of Contracting; Contractor's Workmen; Construction Camps; The Management of Contracts; Contractors Outfit and Plant; A Personal Chapter for the Contractor.

E. McC.

LIBRARY NOTES.

The Library Committee desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

Milwaukee Bureau of Economy and Efficiency.
Recreation Survey. Pam.

Henry G. Tyrrell:
The Evolution of Vertical Lift Bridges, Tyrrell. Pam.

John Wiley & Sons:
A Treatise on Hydraulics, Mansfield Merriman. Cloth.

McGraw-Hill Book Co.:
Centrifugal Pumping Machinery, C. G. de Laval. Cloth.

Chicago City Municipal Library:
Illinois Telephone & Telegraph Co., Ordinances passed by City Council, 2/20/99; 7/15/03; 7/20/03. Pam.

The Electrification of Railway Terminals. (Committee on Local Transportation, City Council.) Pam.

Report on the Investigation of the Chicago Telephone Co., W. J. Hagenah, 1911. Pam.

Report Upon the Price of Gas in Chicago, 1911, E. W. Bemis. Pam.

Report of Sub-Committee on Harbor Development, October, 1911. Pam.

Report on Question of Suitable Regulation of Gas Service for the City of Chicago, by D. C. and Wm. B. Jackson. Pam.

S. G. McMeen and K. B. Miller, M. W. S. E.:
Telephony, McMeen & Miller. Cloth.

C. K. Mohler, M. W. S. E.:
Report on Passenger Subway and Elevated Railroad Development in Chicago, Mohler. Pam.

H. B. Gear, M. W. S. E., and P. F. Williams:
Electric Central Station Distributing Systems, Gear and Williams. Cloth.

H. M. Byllesby & Co.:
H. M. Byllesby & Co. and Affiliated Companies, Proceedings, 1912. Cloth.

M. G. Lloyd, Chicago:
Proceedings, Illinois Water Supply Association, 1911. Pam.
Proceedings, 25th Annual Convention American Street & Interurban Railway Association, 1906. Pam.
Proceedings, 4th Annual Convention American Street & Interurban Engineers' Association, 1906. Pam.
Proceedings, American Railway Mechanical and Electrical Association, 1905. Pam.
Proceedings, American Street & Interurban Railway Claim Agents' Association, 1907. Pam.
Proceedings, American Street & Interurban Railway Accountants' Association, 1907. Pam.
Kansas Gas, Water, Electric Light and Street Railway Association, Proceedings, 1908. Pam.
Proceedings, Minnesota Electrical Association, 1911. Cloth.
Proceedings, Michigan Electrical Association, 1911. Cloth.

EXCHANGES.

American Railway Bridge and Building Association:
Proceedings, 21st Annual Convention, 1911. Cloth.

Society of Engineers, Westminster, Eng.:
Transactions, 1911. Cloth.

Ohio State Board of Health.
Supplement to Annual Report, 1910. Cloth.

Western Australian Institution of Engineers:
Proceedings, November, 1911. Pam.

Ohio Bureau of Inspection and Supervision of Public Offices:
Comparative Statistics, Cities of Ohio, 1909, 1910. 2 pams.

Tennessee Geological Survey:
Bulletin, May, 1912. Pam.

Louisville Water Co.:
Annual Report, 1911. Cloth.

Maryland Geological Survey:
Prince George County; Volume IX of Report. 2 vols., cloth, and 1 box maps.

Junior Institution of Engineers, London.
Transactions, 1910-11. Cloth.

Institution of Civil Engineers, London:
Minutes of Proceedings, Vol. 187. Paper.

May, 1912

American Gas Institute:
Proceedings, 1911, Parts I & II. 2 vols, cloth.

Royal Society of New South Wales:
Proceedings, July, 1911; October, 1911. 2 pams.

GOVERNMENT PUBLICATIONS.

U. S. Geological Survey:
Iron Ore Resources of Michigan in 1911. Pam.
Advance Statement of the Production of Copper, 1911. Pam.
Production of Bauxite and Aluminum in 1911. Pam.
Production of Talc and Soapstone in 1911. Pam.

U. S. Bureau of Education:
1912 Bulletins Nos. 3, 6, 7, 8. Pams.

U. S. Treasury Department.
Hygienic Laboratory Bulletin No. 30. Pam.
Necessity for Safe Water Supplies in the Control of Typhoid Fever. Pam.

U. S. Department of Commerce and Labor:
Technologic Papers of Bureau of Standards, No. 2. Pam.
Technologic Paper, No. 7. Pam.
U. S. Government Specifications for Portland Cement. Pam.

U. S. Bureau of the Census.
Statistics, Manufacturers, Missouri. Pam.
Statistics, Manufacturers, United States, 1910. Pam.

U. S. Bureau of Mines:
Bulletins Nos. 10, 23, 25, 36. Pams.

U. S. War Department, Corps of Engineers:
Bulletin No. 21, Survey of Northern and Northwestern Lakes. Pam.

U. S. Coast and Geodetic Survey:
The Effect of Topography and Isostatic Compensation Upon the Intensity of Gravity. Cloth.

U. S. Commissioner of Education:
Annual Report, 1911. Cloth.

MEMBERSHIP.

Additions:

Gunni Jeppesen, Chicago............................Member
Frank W. Kottke, Chicago..........................Junior Member
Theodor Rall, Chicago ....Associate Member
Ray Palmer, Chicago ....Member
Walter Y. Shaw, Chicago ....Associate Member
Meyer J. Sturm, Chicago...........................Member
Lester E. Voss, Chicago ....Associate Member
Wm. A. Webb, Gary, Ind. ....Associate Member

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ARBITRATION.

Onward Bates, M. W. S. E.

Presented April 1, 1912.

A few years ago an engineer was asked to become one of three members of an arbitration board, as the choice of the writer, who represented one party to the dispute which was to be submitted for arbitration. The other party to the dispute was to select an arbitrator, and the two arbitrators thus chosen were to complete the board by choosing a third arbitrator. It happened that each of the three arbitrators was and is a Member of this Society and of such standing as to command the confidence of the disputants. This board promptly settled the disputed questions and made an award, which was accepted by both parties without any expression of dissatisfaction. The parties had quarreled, some bitterness had developed, they had called each other names which were not mentioned in the specifications, and the only two courses which it seemed would lead to a settlement were a lawsuit or an arbitration. When the writer asked his friend to serve as an arbitrator, he was first met with a refusal and a lecture on the foolishness and wickedness of quarreling. His friend said: "There is no excuse for an arbitration; you should get together and do what is right and settle the matter between yourselves." This was good advice, only it would not work. He did not take into account the fallibility of human nature and the foolishness of the wisdom of men. When he was convinced that the parties could not get together and the intervention of a third party was necessary for adjustment of the differences, he consented to act as an arbitrator, and as such contributed to a settlement which would have been disastrous to even the winner, if it had been obtained in a court of law. Of course parties ought not to disagree; this is inexcusable, and yet they will sometimes disagree and there is no immunity from disputes in this unregenerate world.

A PLEA FOR ARBITRATION.

If it be accepted that there will be disputes among engineers, between themselves or with others, how can these disputes be adjusted? As a people, we have perhaps more law and more determination to have the law on each other than any other people at any other period of history. It is our custom to appeal to the law for settlement of disputes and we are ably assisted and encouraged in making this appeal by our brethren, the lawyers, who are always at hand to get us out of (or into) trouble. The natural result of such free use of the law as a means of offense and defense is a loss of confidence and respect for the means. The flippant saying that "a court room is a place where justice is dispensed with" is not without provocation. To show what the lawyers think on this subject, the following is reprinted from the *Chicago Daily Tribune* of February 1, 1912:

"WOULD REFORM COURT PRACTICE.

BAR ASSOCIATION SUGGESTS NEW RULES AND A CHANGE OF PROCEDURE. MORAL DEFECTS POINTED.

PHILIP STEIN SAYS TWO DEFENSES OFTEN GIVE THE LIE TO EACH OTHER.

Members of the Chicago Bar Association planned last night at their monthly dinner to use their influence to reform the practice and procedure of the Illinois courts.

Judge Cutting, who was the speaker of the evening, said the chief reason why members were discussing such a reform was the demand throughout the United States that legal procedure be 'more effective, more speedy, and more just.'

Philip Stein expressed, in a letter read by President Edgar B. Tolman, a view which was applauded by those present:

'The great, and in my opinion chief, trouble with our administration of the law is that a trial in court is regarded and treated as a battle in which the combatants may, without loss of self-respect, use all means not bordering on the downright criminal to gain their ends, and, if deemed expedient, to obstruct the cause of justice,' he wrote.

'This view is so deeply rooted that as a rule it rarely occurs to the practitioner that there is anything immoral in pleading two inconsistent defenses, each of which gives the lie to the other, and that when it does occur to him he justifies the practice upon the principle that everything is fair in war.

'It does not occur to him that a proceeding in court should not be a fight, but solely an investigation by the court, with the assistance of counsel, into the merits of the respec-

tive claims for the purpose of ascertaining where the truth lies, what the facts are, and then applying the rules of law applicable thereto.'

Charles E. Kremer explained the simplicity of procedure in courts of admiralty:

> 'We proceed in courts of admiralty as if they were courts of justice,' he said. 'The procedure in the state courts is such an abomination that if the laymen knew as much about the practice as we do they would rise and smite it.'"

It is not to be inferred that Illinois' courts are worse than those in other states, and Judge Cutting's statement of "the demand throughout the United States that legal procedure be more effective, more speedy, and more just" is of general application. The uncertainty of legal procedure has become so fixed in the minds of laymen that men desiring justice will hesitate to appeal for it in the law courts, anticipating that judgments may not become effective until reviewed by the Supreme Court, that litigation under our system is limited by cost and not by time, and that the termination of it may be a miscarriage of justice. Men in this state of mind ought to welcome a method of adjusting differences occurring in the conduct of their business which offers a saving in time and cost when compared with the usual process of law, and it is the purpose of this paper to propose arbitration as such a method, with some suggestion as to the application of the method, and the nature of disputes to which it may be applied.

Settlement of controversies by arbitration is not an evasion of law, for an arbitration which violates the law is unlawful and the award will be without binding effect. The same difficulty exists in a court trial, as is shown by the exceptions filed and appeals from court to court, charges and counter-charges, and almost endless delay and confusion of the questions involved, until litigants are mentally and physically exhausted and willing to end the matter on any terms. The writer is not competent to criticise the practice of law, and relies on the testimony of the lawyers themselves, to which end he has already quoted the discussion at a meeting of the Chicago Bar Association. Neither is there anything new in the principle of arbitration. The settlement of disputes by arbitration is coincident with the efforts of men to secure justice. The more or less popular demand now agitated by citizens of this country for the recall of elected officials, including judges, however harmful such a course may prove to be, is nevertheless an expression of dissatisfaction with existing conditions and of a desire of the people to take matters in their own hands and become their own arbitrators. The value of arbitration as a means of settling controversies is recognized and the statutes of different states contain laws govern-

ing arbitrations and awards. The Chamber of Commerce of the State of New York published last year a pamphlet entitled "Commercial Arbitration," showing a method established by that body for the adjustment, without litigation, of differences arising between individuals, firms, or corporations. The writer is informed that commercial arbitration has been practiced under this method with satisfactory results. This published method contains the record of thorough investigation of the subject and it may be studied with profit. The writer hereby acknowledges his indebtedness to this publication for the liberal extracts from it, which are introduced into this paper. No apology is offered for inserting so much that is not original, because it is warranted by its pertinency.

The special committee on Commercial Arbitration of the Chamber of Commerce of the State of New York, in a search for the best and most suitable method of arbitration for adoption by the Chamber, studied the Charters and By-Laws of the New York Stock, Produce, and Cotton Exchanges; of eleven American Chambers of Commerce, and Boards of Trade, of three such bodies in Canada, of the London Chamber of Commerce, and the Consular Reports on Commercial Courts of Europe.

The writer, in support of his plea for arbitration, quotes from that committee's report as follows:

> "The Consular Reports of the experience of Commercial Courts on the European Continent, show that they are successful almost without exception, and that they enjoy the respect and confidence of their respective commercial communities. The New York Chamber of Commerce, cannot, however, pattern an Arbitration Court on the lines and plans of these Courts because of fundamental differences in laws, customs and view-points. The London Court of Arbitration is probably a better guide, because of the similarity between English institutions and our own.
>
> Your Committee deems it of sufficient importance to the Chamber to introduce at this point in its presentation extracts from an address delivered on February 19, 1909, by Sir Albert K. Rollit, Ex-President of the Chamber of Commerce of London, and Chairman of its Arbitration Committee, on the subject of Commercial Arbitration as practiced at the London Court of Arbitration:
>
> 'Arbitration is indeed the natural right of disputants to choose their own tribunal, and is the practical art of vindicating and reconciling disputants, and doing so at a minimum of expenditure, time, and trouble.
>
> Except for arbitration there would be many cases in which justice would be denied.
>
> Even rough and ready trade arbitrations are necessary to modern commercial life.

There is no rivalry in arbitration with the law or the administration of the law.

The work of the London Court of Arbitration is speedily done, and affords the disputants the opportunity of choosing their own commercial court and judges. As the suitors choose their own judges, there can be no appeal, except on points of law or misconduct.

The proceedings have the advantage that the Arbitrator is both judge and jury; and being generally selected for his trade knowledge, which dispenses with numberless witnesses, permits of cases being dealt with in a manner which would be impossible from the Bench.

Many of the cases have been heavy and important; in one the Court has been asked not only to judge and revise resolutions passed by the directors of a company, but to substitute, if it thought proper, such resolutions as should, under the circumstances and in its judgment, have been passed in the interest of the company.

In regard to international arbitrations, steps are being taken to arrange for giving legal effect to those cases in which citizens of Great Britain and other nations are interested, or in which such citizens may become parties to an arbitration.'"

The committee presented "a brief synopsis of the experiences of the Chamber in the past in endeavoring to provide opportunities for Commercial Arbitration, giving in concise form from the *modus operandi* of each period and some reasons for the discontinuance of each method respectively." This synopsis covers the period from 1768 to the present date and the committee states:

"From the very date of organization, the Chamber's Committees on Arbitration and Committee on Appeal were used frequently, and in the main gave great satisfaction. The weakness disclosed in this plan was that parties could withdraw *after* arbitration had begun, and *before* award had been made; and no method existed for enforcing the awards."

In 1875 a Court of Arbitration was established. This method of arbitration was not satisfactory and as a record of experience which ought not to be repeated the committee's report on this court is copied in full:

"PERIOD FROM 1874 TO 1895.

Arbitration by Court of Arbitration. Judge Enoch L. Fancher, Official Arbitrator, and George Wilson, Arbitration Clerk, both appointed by the Governor of the State under Chapter 278 of the Laws of 1874, and Chapter 495 of the Laws of 1875. Mr. Elliot F. Shepard was the leader in the formation of this Court. The plan as long as it remained

operative was eminently successful, but was open to these criticisms:

1. Its financial support was precarious; it was left to the Legislature, which, after 1878, refused to make appropriation;

2. The plan attempted to cover every kind of commercial dispute and to dispose of it Court-fashion;

3. It attempted to give merchants in the Port of New York a special court, and in that respect was treated by the community as 'class legislation'; and met with much unpopularity.

Your Committee is of the opinion that the Statute providing for a Court of Commerce need not be revived at this time. It does not, in its judgment, furnish the best model to be followed. The method of 1768 to 1861, though rough and ready, re-enforced by the Law of Arbitration under the Code of Civil Procedure, Sections 2365 to 2386 (providing that a decision of the Board of Arbitration can be made the basis of judgment in a Court of Record), seems to us to offer more elements for a feasible plan. The one submitted, supplemented by the regulations and rules that a Committee on Arbitration shall make for its proceedings, particularly in regard to the 'Submission' to be signed by the disputants, your Committee feels confident will meet existing needs.

Dependence on the Legislature for support, in their effort to make the award a binding one, is the rock on which most arbitration plans of this Chamber have come to grief. The enforcement of the award is recognized by your Committee as of great importance, but after consideration it believes that to rest the entire plan upon this phase of it is equivalent to sacrificing the whole to save a part. This weakness and possibly others are, in our judgment, offset by certain strong moral considerations that it does not seem unreasonable to rely upon:

(1) The voluntary submission in good faith to the Chamber on the part of both disputants, makes it likely that neither will withdraw after arbitration has begun and before the award is made and that both will be satisfied with the result; and

(2) It is not probable that a merchant would be willing to blemish his fair name by repudiating a written agreement with a reputable body of public-spirited men."

The committee concluded its report with the following remarks:

"Where two parties have an honest difference of opinion, arbitration offers the best results. In cases where one of the parties means to be dishonest, there is no room for

arbitration. *Prima facie* examination of the 'Submission' will, in most instances, determine whether a case should be heard or dismissed.

Finally, it is your Committee's opinion that the plan as outlined by them will give satisfaction, and offers the facilities that are so much needed. They believe this plan affords the opportunity to merchants to settle with the assistance of a public-spirited body of unbiased men (without too great a call on their time), many minor commercial disputes which, when compromised, tend to lower the standard of commercial integrity, or when forced into court produce rancor, unnecessary waste of time and money, and untold annoyance as well as long delay in the courts in the disposition of those matters for which they are specially organized."

On February 2, 1911, the Chamber of Commerce, in consequence of the committee's report, adopted amendments to its By-laws establishing the method of arbitration and defining the duties of the Committee on Arbitration. On June 1, 1911, the oath of office was administered to the "Committee on Arbitration of the Chamber of Commerce of the State of New York" by the Honorable Vernon M. Davis, Justice of the Supreme Court of New York. The address of Mr. Justice Davis to the Chamber of Commerce on that occasion was as follows:

"Mr. President, and gentlemen of the Chamber: As your President has said, my presence here today is explained by the statute under which your Committee on Arbitration has been formed. That Committee is required to take the oath of office, and that oath has just been administered. Although it is always an honor to any citizen to be invited to attend a meeting of this august body, I do not take this invitation as a personal compliment to myself, but rather as an expression on your part of a desire to bring your system of arbitration into full co-operation with the Supreme Court of the State of New York, and I may say to the members of this Committee on Arbitration that the confidence implied in being selected as an arbitrator by the business men of this community is a reason for just pride on the part of those selected.

I know of no other function of business life more useful than that of acting as an impartial judge between business men in their various disputes. The time and trouble incident to your office will be great, but the sacrifices you make will entitle you to the lasting gratitude of a very large and important part of the business community, and indeed of the people of this great city.

I sincerely congratulate you upon your appointment to the high office which you have now assumed. I also congratulate this Chamber of Commerce upon bringing again

into existence a simple and effective plan for settling business disagreements without resort to the courts. In this, as in many other things, the Chamber has maintained its character of being alive to all public needs, and has performed an important public service. Why should business men undertake long and expensive litigation over ordinary differences arising between them? I think it must be a habit, and a bad habit too. I am hopeful to predict, and I appeal to your experience to justify that prediction, that a very large number of the disputes that are now carried to the courts will be settled speedily and inexpensively under the scheme of arbitration which has just been adopted by this Chamber. Of course there remain many controversies impossible of settlement without the aid of judges and courts—cases where the facts to be established depend on the conflicting testimony of many witnesses, and the judgment to be pronounced requires the decision of intricate questions of law. Such cases will still go to the courts and not to arbitration.

The plan adopted by the Chamber is in no sense in competition with the courts, nor can it be justly regarded as a protest against any real or fancied delay in the administration of justice in this city. It has arisen out of an obvious condition of business life here, the obvious fact that it is practicable to avoid the delay and expense of a suit in court by a resort to arbitration, and the courts look upon these settlements with great favor, and it is the policy of the law to encourage arbitration, so much so that by special statute the awards of arbitrators may become the judgment of the Supreme Court, judgments of as high a sanction as those obtained in the formal litigation in the courts.

The business community is fortunate in being able now to call to its services as arbitrators, through your initiative, so many men of experience. Arbitration as you have established it will become an important part of business life, and it will continue so long as the simple principle of arbitration is maintained, and so long as it avoids the strict formalities of the courts. It will not do to develop this plan of arbitration into an arbitration court. This Chamber has had experience with an arbitration court. We shall long remember, and with great respect, the valuable services of the court presided over by that distinguished jurist, Judge Fancher, but the ultimate extinction of that court seemed inevitable, as it was not quite in line with the constitutional principles of our institutions, and its decisions were arrived at not informally, but with increasing formality, reaching unto the dignity of a court of justice. That result should be avoided in the plan which you have adopted. It should maintain its simplicity, its lack of formality, and there should be, as I

> believe there will be, a ready submission to its awards; and this plan of arbitration, if it meets with favor, we can imagine being extended throughout the length and breadth of this land. If it is useful, it will be so extended, it will be so maintained, and who can tell the effect of such a plan as this, and its educational value upon the development of patriotism? It will bring into business life more charity, and less harshness, more humanity, and it may develop a strong sentiment in favor of a higher form of arbitration, the arbitration of disputes between nations, and as a result of that, the development of a higher form of patriotism, patriotism that is based not only upon love of country, but upon the love of our fellow men.
>
> Gentlemen, I bespeak for this Committee on Arbitration the fullest confidence of the business community of this City. I believe it will be a great success, and that it will save lots of money and lots of time."

The lessons to be learned from the preceding study of commercial arbitration are equally applicable to engineering arbitration, since engineering is an ally of commerce, and questions likely to be submitted for arbitration will be commercial in their nature. It is hard to conceive any controversies which are not as susceptible of settlement by arbitration as by the usual process of court trials. At this present time it is proposed by eminent statesmen that all questions of dispute between nations may be settled by arbitration. The President of the United States fully committed himself to this doctrine in an address delivered by him on "The Proposed Arbitration Treaties with Great Britain and France," at the meeting of the "American Society for Judicial Settlement of International Disputes," held in Cincinnati last November. President Taft was a distinguished lawyer and judge before he was elected the chief executive of this nation, and there is no higher authority on this subject. The following quotations are taken from his address:

> "I am glad to be here today, because it is only about a year ago that I had the honor of attending a banquet of this same Society, and of repeating at that banquet what I had ventured to say only casually some six months before, to wit: That I had noticed in a number of our treaties with foreign nations that there were excepted from the causes which were to be arbitrated those which involved national honor or vital interest; that I did not see any reason why we might not just as well arbitrate a question of national honor or vital interest as anything else. That observation was followed at the banquet of this Society a year ago by the statement that I hoped we might be able to make a treaty with some prominent nation in Europe by which we

would agree to arbitrate every controversy that could arise between us, whether it involved national honor or vital interest or not. * * * It struck me, as I am sure it must strike you when you read a treaty that says 'We will agree to arbitrate everything that arises between us except questions of national honor or vital interest,' that you have omitted, from the things which you are to arbitrate, about everything that is likely to lead to war. At least, you have put into the treaty words which any nation that desires to avoid arbitration can fall back upon as including everything that they wish to include within that description.

So far, therefore, as facilitating peace and avoiding war are concerned, these treaties might just as well have been written in water, except that they express the general desire to arbitrate when it is easier to arbitrate than otherwise.

Now, I am asked 'Would you arbitrate a question of national honor?' I have no hesitation in answering that exactly as it is put: I would much prefer to submit to a board of arbitration, composed of intelligent jurists of an impartial mind, the question whether our national honor has been attacked, and if so, what the reparation of the injuring nation ought to be, than to go to war about it. * * * I think we ought to come to a point where we will not take positions that cannot be sustained under the rules of law and equity."

There are those who do not agree with our President, and the writer does not expect all who read this to accept his plea for arbitration. Where there is agreement there is no case for arbitration, but as there always will be disagreements, arbitration is offered to engineers as a convenient method of settling disputes in conformity with justice and reason.

LEGAL ADVICE.

A proposal for arbitration does not contemplate doing away with the law, neither does it advocate it as a means for dispensing with the services of lawyers. No man can arbitrate a point of law itself, although arbitrators may study the facts and consider them as if they were both judge and jury and may make awards which could not be obtained under the law. The arbitrator is confined in his award to a decision based on justice and reason, whether that decision be justified by law or not, but he can in no case do that which is unlawful.

The processes of arbitration may vary from the simplest reference of a dispute to a third party, to complicated cases with voluminous testimony and in which the award is made the judgment of a court of record. In the former case *A* and *B* may have a controversy in a certain matter and agree to refer it to *C*

and that they will accept his decision. This is legal, and is as binding as any similar agreement can be between *A* and *B*. In the latter case, when it is desired that the award shall be made a court judgment, the proceedings must conform to the laws of the State relating to arbitration. In any case the laws of the State must be observed, for a violation of these laws will render the award void and without effect. The parties submit their case to arbitration because they fear that litigation may be expensive and tedious and may not result in satisfaction. Their instrument of submission must disclose the controversy and the questions at issue and unless these questions are simple they should be formulated with legal advice. The arbitrators are chosen for their supposed qualities of integrity, judgment and knowledge, which qualify them to make an award in accordance with justice and reason. They are not expected to be familiar with the rules of legal procedure and are engaged to make a decision based on the facts in the case. Arbitrators may not employ counsel to aid them in making decisions, but it is proper and sometimes necessary that they shall have advice regarding the extent and limitations of their powers as arbitrators. It is therefore apparent that in the substitution of arbitration for court practice, a knowledge of the laws to be observed is required of the parties to the dispute and of the arbitrators, and that the advice of lawyers may be required by each of them.

THE SUBMISSION.

The submission is a statement of the subject matter of the controversy, in which the parties voluntarily submit the matters in dispute, and all matters concerning it, to the arbitrator or arbitrators. It corresponds with the pleadings in a court of law.

It should be a formal and complete statement of the scope of the arbitration.

It should show that the parties agree to stand to, abide by, and perform, any and all decisions, awards, orders, and judgment that may be made by the arbitrators.

It should contain a waiver of the right to withdraw or revoke the submission after the arbitrator or arbitrators have accepted their appointment, except by mutual agreement of the parties who subscribed to the submission.

When a court judgment is desired by the parties, the submission should contain an agreement for entering such judgment in some stated court.

The submission must be made by parties legally capable of entering into a submission.

The submission must be for the determination of cases which can legally be submitted for arbitration.

The submission should refer to the statutes under which the arbitration is to be conducted.

The submission should be in writing and should be signed by the parties, with all of the precautions and formalities necessary to make the instrument binding upon them, whether they be individuals, firms, or corporations.

The above-mentioned requirements emphasize the importance of the most thorough and careful preparation of the submission.

The submission may be amended at any time previous to the first hearing before arbitrators.

NUMBER OF ARBITRATORS.

Arbitration is the voluntary exercise of "the natural right of disputants to choose their own tribunal." Consequently, the arbitrators are appointed by the parties signing the submission. The parties may agree that one arbitrator is sufficient, or they may choose a number of arbitrators who shall constitute a board of arbitration. The parties have thus complete control of the selection of their tribunal, and in making this selection they close all doors of appeal from the lawful decisions of their chosen arbitrators.

There may be cases where one arbitrator is sufficient, and to be preferred to a number of them. The nature of such a case and the confidence of both parties in the parties considered for arbitrators will determine whether one is sufficient. If more than one arbitrator is desired, the board should consist of three or of five arbitrators in order that there may be no even division among them. Three arbitrators are usually preferable to five on account of the difficulty in securing full attendance at the hearings and meetings of the board. There are many causes which tend to extend arbitration cases over considerable periods of time and as arbitrators are usually men of affairs who are much engrossed with their other business, a board is much more unwieldy than a single member, and it is more difficult to secure the time and attention of five men than of three men. A common practice when there are two parties to the dispute is for each party to choose one arbitrator, and these two arbitrators to select a third arbitrator. This practice is objectionable, for the practical result is almost certain to be that the first two arbitrators chosen, feel, in some degree at least, that they represent the parties who chose them, and the third arbitrator feels that he is an umpire between two partisans. Such practice is directly opposed to the principle of arbitration as a method of securing just and equitable awards. It is really expecting too much of human nature and is placing the first two arbitrators in a position which is not fair to them. When there are more than two parties to the dispute this method of selecting arbitrators is still more complicated and objectionable. The only correct method of choosing arbitrators is for all

the parties to the dispute to agree upon them so that each arbitrator will feel that he equally represents all the parties.

QUALIFICATIONS OF ARBITRATORS.

Much of what will follow under the next several titles is gleaned from a *Hand Book for Arbitrators,* prepared for their guidance by Julius Henry Cohen, of the New York Bar, at the request of the Committee on Arbitration of the Chamber of Commerce of the State of New York. This acknowledgment will cover extracts taken verbatim and indicated as quotations, and in addition, ideas borrowed from Mr. Cohen's handbook and expressed in the writer's own language:

> "It goes without saying that the arbitrators should not be related in any way to either side, nor be interested in any fashion whatever. More than that, they should not be biased or prejudiced against either of the parties.
>
> Any person interested in the event or related in any way to either of the parties, or biased or prejudiced, is disqualified.
>
> Almost every business man is accustomed to listen patiently to facts and to form conclusions thereon. On the other hand, not many men have the patience to sift evidence and discuss differences. Having reached a conclusion in their own way, by their own individual mental processes, most business men are reluctant to go through the irksome process of convincing others of the soundness of their deductions. The wise arbitrator will not only deliberate with great pains, but will listen with patience to everything that can be said upon the subject and refuse to render final judgment until he has heard all that can be said. The experienced man knows that a slight change in circumstances may result in entirely different conclusions.
>
> A testy or impatient judge may sometimes do justice, but very frequently does quite the contrary. A painstaking, considerate judge will not only earn the gratitude of the disputants, but when his decision is rendered, it will be accepted with good grace and with confidence in its fairness."

The writer is not in full agreement with the first statement quoted above. A strict observance of the stated qualifications may reject a person capable of serving, and who is acceptable to all the disputants. There are many ways in which sympathy or prejudice may exist between a disputant and a possible arbitrator, and if the same policy is adopted in selecting an arbitrator as in choosing a jury we may expect as in the latter case that the best men are not always selected. A single illustration which will be appreciated by engineers will be sufficient to explain

the preceding statement. Take a common case of dispute where the parties are represented on the one side by an engineer and on the other side by a contractor. Now, an engineer who is considered for the office of arbitrator may be personally unacquainted with the engineer disputant, and yet may belong to the same profession and possibly to the same engineering society, and it is not unnatural if he has a sympathy or bias toward his brother engineer. The same argument may apply to a contractor. It is natural that a party will choose a friend because of his confidence in his character and his knowledge of his ability, but the fact that he is a friend should not disqualify him if he is acceptable to the other party. The writer would rule that in each case every question of relationship or sympathy or prejudice should be looked into by the disputants, and if, after investigation, all the disputants agree to accept either the engineer or the contractor as an arbitrator, he is qualified to serve as such, for the simple reason that the parties have the right to choose their arbitrators.

Aside from any question of relationship between arbitrators and disputants, there are questions of competency as a judge. Integrity is, of course, a first consideration, a judicial mind, a patient and painstaking habit of work, a capacity for dealing with problems in a methodical and systematic manner, and a knowledge based on experience in the occupation or business where the dispute originated, are all essential elements of competency as an arbitrator. How much weight must be given to the qualification of experience is something which must be determined by the disputants. An arbitrator may be chosen for his knowledge and experience in some particular item of work or material which may be the crux of the dispute, and yet this very experience may be a disqualification. His opinion may be based on experience gained under conditions different from those in the disputed case, and he may have acquired such fixed opinions and such a practical bias that he cannot properly weigh the evidence of other experts and give it a fair value. Judicial temperament and a general knowledge of the subject in dispute, coupled with an ability to sift evidence and to place a true value on the knowledge of others is more desirable in an arbitrator than is his own expert knowledge.

If the parties cannot name to each other men who are jointly acceptable to them, they can at least agree upon disinterested parties, to whom they can delegate authority to choose the arbitrators.

DUTIES, POWERS, AND LIMITATIONS OF ARBITRATORS.

"The basis of authority of the arbitrators is to be found in the submission, signed by the parties, by which they voluntarily submit the controversy, dispute, or matter of difference between them relating to the subject matter stated

in the formal submission, to which reference must be made by the arbitrators for the purpose of determining what the controversy, dispute, or matter of difference may be."

Under this submission the arbitrators are empowered and required to make a decision which must be a "mutual, final, and definite award upon the subject matter submitted."

"They have the power to follow or disregard rules of law. All questions of law or fact upon which the rights of either party depend in the controversy are submitted for final decision to the arbitrators. They may disregard the strict rules of law and evidence, and decide according to their sense of equity, but any violation of natural justice by an arbitrator, such as receiving material evidence from one of the parties without the knowledge or consent of the other is condemned by the Courts, and in several cases awards have been set aside for such reasons. It has been held that even if the arbitrator be a lawyer, he may disregard the rules of law and decide according to his own idea of the justice of the case."

They are required to proceed with diligence to hear and determine the matters in controversy.

Prior to any hearing of testimony in the cause, the arbitrators shall be sworn faithfully and fairly to hear, examine, and determine the cause, according to the principles of equity and justice, and to make a just and true award according to the best of their understanding. This oath shall be administered and certified to by an officer legally qualified under the statutes. This oath is not, however, necessary if it is waived by the consent of the parties to the submission.

The arbitrators must appoint a time and place for the hearing of the matters submitted to them, and must cause notice thereof to be given to each of the parties. They, or a majority of them, may adjourn the hearing from time to time upon the application of either party, for good cause shown, or upon their own motion; but not beyond the day fixed in the submission for rendering their award, unless the time so fixed is extended by the written consent of the parties to the submission. In the case of a "suit pending" the arbitrators may not extend the time for such hearing beyond the next term of the court in which the suit is pending, if the subject matter be in suit.

Arbitrators have power to compel the attendance of witnesses, etc., which is given them under the State Codes. This point is covered by the Revised Statutes of Illinois, Chapter 10, as follows:

> *"Subpenas—Witnesses Swearing Same:*
>
> Section 4. The several clerks of the Circuit Courts, and the justices of the peace in their several counties, may issue subpenas for the attendance of witnesses before arbitrators; if any witness, after being duly summoned, shall fail to attend, the arbitrators may issue an attachment to compel his attendance, and the said witness shall morever be liable to the party for refusing to attend the same as in trials at law. Any one of the arbitrators may administer oaths and affirmations to witnesses; they may punish contempts committed in their presence during the hearing of a cause, the same as a court of record, and may admit depositions to be read in evidence, the same as in trials at law."

The Illinois Statutes provide for compelling arbitrators to duty, as follows:

> *"Arbitrators Compelled to Duty:*
>
> Section 14. Arbitrators may be compelled, by order of the court in which any cause submitted to them shall be pending, to proceed to a hearing thereof, and to make report without unnecessary delay."

All arbitrators should attend throughout each hearing in the cause submitted to them. The Statutes of Illinois permit a majority of them to hear and determine the matters in controversy, while the New York Statutes require all of the arbitrators to meet together and hear all the allegations and proofs of the parties. In both states an award by a majority of the arbitrators is valid, unless the concurrence of all is expressly required in the submission.

Since the submission of a cause to arbitration and the appointment of arbitrators is a contract in itself which does not contemplate the revocation or withdrawal of any of the parties or arbitrators (except by mutual agreement), and is intended to secure a final and complete adjudication of the controversy, it is apparent that the instrument of submission must in itself be complete; and in illustration of some of the points to be covered by the submission, the code provisions relating to law of arbitration in the State of New York are quoted by title as follows:

2365. When submission to arbitration cannot be made.
2366. What controversies may be submitted, and how.
2367. Appointment of additional arbitrator or umpire.
2368. Time for hearing; adjournment, etc.
2369. Arbitrators to be sworn.
2370. Attendance of witnesses, etc.
2371. All the arbitrators to meet; when majority may award. Fees.
2372. Award; to be authenticated, etc.
2373. Motion to confirm award.

2374. Motion; to vacate award.
2375. Motion; to modify or correct award.
2376. Motions; when to be made.
2377. Costs on vacating award.
2378. Judgment on award; when and how entered; costs.
2379. Judgment—roll.
2380. Effect of judgment; how enforced.
2381. Appeal.
2382. Effect of party's death, lunacy, etc.; proceedings thereupon.
2383. Revocation of submission.
2384. Liability of party who revokes.
2385. Limitation of recovery against him.
2386. Application of this title.

In order to show the limitations of arbitrators, Sections 2374 and 2375 of the New York Code are quoted below in full:

"2374. Motion; to vacate award:

In either of the following cases, the court, specified in the submission, must make an order vacating the award, upon the application of either party to the submission:

1. Where the award was procured by corruption, fraud, or other undue means.

2. Where there was evident partiality or corruption in the arbitrators, or either of them.

3. Where the arbitrators were guilty of misconduct, in refusing to postpone the hearing, upon sufficient cause shown, or in refusing to hear evidence, pertinent and material to the controversy; or of any other misbehavior, by which the rights of any party have been prejudiced.

4. Where the arbitrators exceeded their powers, or so imperfectly executed them, that a mutual, final, and definite award, upon the subject matter submitted, was not made.

Where an award is vacated, and the time, within which the submission requires the award to be made, has not expired, the court may, in its discretion, direct a rehearing by the arbitrators.

2375. Motion; to modify or correct award:

In either of the following cases, the court, specified in the submission, must make an order modifying or correcting the award, upon the application of either party to the submission:

1. Where there was an evident miscalculation of figures, or an evident mistake in the description of any person, thing, or property, referred to in the award.

2. Where the arbitrators have awarded upon a matter not submitted to them, not affecting the merits of the decision upon the matters submitted.

3. Where the award is imperfect in a matter of form, not affecting the merits of the controversy, and, if it had been a referee's report, the defect could have been amended or disregarded by the court.

The order may modify and correct the award, so as to effect the intent thereof, and promote justice between the parties."

The arbitrators have power to fix their own method of procedure. The question of procedure is so clearly discussed in Mr. Cohen's *Handbook for Arbitrators,* previously referred to, that the writer cannot do better than to quote him as follows:

"The arbitrators should, after taking the oath, read the submission and, before taking any evidence, for the purpose of familiarizing themselves with the points in controversy, ask both sides to present their points of view. They should then decide the order in which they will take proof and in what order they care to hear witnesses. This procedure they may regulate in each case according to their discretion, but they must, before the proceeding is closed, take and consider all evidence that is material and pertinent to the controversy that is offered by either party. They should give the parties full opportunity to produce witnesses and documents. Where documents are in the possession of either party that the other desires to examine, they should require the party in possession of the documents to produce them for examination. They should, within reasonable limits, permit cross-examination of witnesses. The party who calls the witness should not be permitted to put the words into the witness' mouth by asking leading questions, nor should time be spent upon evidence that has no relation to the controversy whatever. All collateral issues should be avoided. In case the parties have a reasonable excuse for not being ready on the trial day, the arbitrators should adjourn the hearing. They should facilitate the taking of testimony outside of the State, if in their judgment they think such testimony will assist them in determining a controversy. They should receive the testimony of experts called by either of the parties, and may receive the tabulations of accountants for the purpose of assisting them in arriving at a conclusion.

They should permit the parties fully to discuss the issues before them and to sum up the case. If any law points are involved, they should disregard pure technicalities and go to the merits. If they believe that the legal proposition is based upon sound sense and the experience of mankind generally, they should follow it. They may, if they desire information as to the law on any point, consult counsel not interested in the case.

In this connection, they should bear in mind that their decision is not only of value in deciding the controversy for the parties in interest, but will form also a precedent for the future guidance of other arbitrators in deciding similar disputes. A series of commercial precedents has a very important value to the business community, and the certainty of knowing how important questions will be answered will serve to prevent controversies in the future. For this reason, where the matter is of sufficient consequence, a written opinion by the arbitrators, like the opinion of the court, is of very substantial value to the commercial community as a precedent."

MEDIATION AND COMPROMISE.

When parties submit a case to arbitration, the act of submission is good evidence that they do not expect to compromise it, and the arbitrators appointed under the instrument of submission have no authority to act as mediators, or to propose compromises between the parties, although they are not forbidden to do either. Some persons think an arbitrator has no right to act as a mediator and that he cannot do so without discrediting himself as an arbitrator. On the other hand, others hold it to be an arbitrator's duty to propose a compromise if he thinks it the best solution of the difficulty for both parties. In favor of the latter course it may be said that submission of the case to arbitration is a voluntary act of the parties, entered into at a time when a compromise seemed to them impossible, but if the testimony should shed a new light on the case, or if the arbitrators should call their attention to points overlooked by them leading them to change their minds, they may agree to compromise the case in preference to continuing the arbitration proceedings, and may, by mutual agreement revoke the submission at any time before the allegations and proofs have been closed. Arbitrators are appointed to make a just and reasonable award, and if justice and reason can be satisfied by a compromise which the contestants agree will be to their advantage, the arbitrators would be justified in proposing such a compromise. A compromise is "a settlement by arbitration or by mutual consent, reached by concessions on both sides," and to compromise means "to make concessions for conciliation and peace." The "pound of flesh" theory has no place in arbitration, and it is hard to conceive an arbitrator's award in a case that is complicated (as most of them are) which does not require concessions from parties to the submission. In some court trials and also in some arbitration cases an award is found to be more expensive to all parties than a compromise, and, if such a statement is not parodoxical, it may be said that justice is secured at the expense of reason.

Parties are sometimes unable to reach a settlement for rea-

sons quite aside from the merits of their controversy. Each party may have committed himself by saying he has reached the limit and will make no further concessions. This is the stage in which the matter is submitted to arbitration. A little more concession by either party would settle the matter, and neither is willing to concede anything more. Consequently time is consumed and heavy expenses incurred by an arbitration, and if the parties are acting in representative capacity it is the owners or stockholders who are the real sufferers. An arbitrator under these conditions is justified in including these necessary concessions in his award, or, in what may be a better way, acting as a mediator by advising the parties to agree to the concessions and to jointly revoke the submission. If the parties are reasonable they will welcome an opportunity to "save their faces" and at the same time come to a satisfactory settlement.

The following hypothetical case will illustrate the difficulty in an exact determination of justice and the reasonableness of a compromise:

A and *B* had joint work at two different places and they verbally agreed that *A* would do the work at one place and bill against *B* for the latter's share of the cost, and that *B* would do the work at the other place and bill against *A* for his share of the cost. This original agreement was never questioned but *A* and *B* fell into a dispute over the bills which they submitted to each other. It happened that the work was done in a rainy season, at costs greater than had been anticipated; expensive delays occurred, and the subordinates of *A* and *B,* in immediate charge of the work, quarreled over the monthly bills. This controversy lasted a couple of years and at every turn was burdened with charges and complaints that were not properly sustained by evidence. Finally *A* and *B* got together and tried to settle the matter, but the details of the controversy had become so numerous and intricate that they could not take the time necessary to unravel them. Both *A* and *B* had by this time become influenced by the representations of their subordinates and were not in the mood for a compromise, so they decided to submit the matter to *C* for arbitration. At this date the witnesses were scattered abroad, facts and conditions were forgotten, and a mass of testimony was on file, in which the truth was buried like a needle in a haystack. After much study of the evidence *C* was unable to satisfy himself as to the merits of the case. He then sent for *A* and *B* and managed to obtain some concessions from each, which reduced the amount at issue between them. When *A* and *B* would go no further, each saying he had reached his limit, *C* cut the gordian knot by "splitting the difference" between them, explaining that justice was so obscured he could only bring the controversy to a reasonable end by this compromise decision which either party could rightly reject. *A* and

B realized that it was better to end the dispute in this way than it was to prolong it, and both accepted the decision without protest.

In the case described above the allegations and proofs of the parties were the weak features of the arbitration, as they would likewise have been in a suit at law, and as they did not enable the arbitrator "to make a just and true award according to the best of his understanding," he was justified in proposing a compromise, and this compromise was equivalent to an award when it was accepted by the parties.

The writer holds that mediation and compromise may properly be proposed by an arbitrator, subject to the joint acceptance of the parties to the submission.

A proposed arbitrator may find, when he looks into a case to determine whether he will accept the office, that arbitration is proposed on account of a heated state of mind on the part of the disputants, and that arbitration, in this case, is unnecessary and unwise, and if he can mediate between the parties and obtain a settlement without arbitration, he has served them better and with more credit to himself than if he acted as an arbitrator.

CASES WHICH MAY BE ARBITRATED.

It is impossible to enumerate all the cases which may properly be submitted to arbitration. A general statement of such cases is comprised under the term "justiciable differences," meaning all differences "susceptible of decision by the application of the principles of law and equity."

This paper is written for engineers, by an engineer, and the mind of the writer naturally turns toward the cases which an engineer may expect to meet in the practice of his profession. The commonest examples of such cases are to be found in work performed and material furnished under engineering contracts. The contract almost invariably provides that the engineer for the party paying for the work or material shall be the sole judge of the sufficiency and quality of the work and material furnished by the other party to the contract; that all controversies arising under the contract shall be submitted to him for decision, and that his decision shall be final and binding on the contractor. This reads like foolishness and yet it is a common stipulation in an engineering contract. It seems as if engineers and lawyers had conspired together to formulate contracts giving the engineer arbitrary power over the contractor, power exceeding that permitted by the law of the land, and which, when subjected to the light of the law, is found to be without effect, and showing weakness instead of power when tested. It is true that contract work has been done, and is being carried on, under such contracts; sometimes with great satisfaction to the parties to the contract; at other times without satisfaction, and yet without open rup-

ture, and at still other times resulting in serious controversies. It may be that trouble only arises when the engineer is inexperienced or incompetent, or has a bad disposition, but there is no way to guarantee that engineers will not possess more or less of these disqualifications and it is contrary to public policy, which stands for the natural rights of men, that contractors should be forced into the acceptance of contracts containing such objectionable features. It is time that engineers, for the sake of their own self-respect, should eliminate these features from contracts. A contract which provides that the engineer shall be the arbitrator between the engineer's employer and a party whose remuneration comes from the engineer's report to that employer, is in reality a tripartite agreement, the three parties to the contract being the engineer's employer, the contractor, and the engineer, which agreement provides that the engineer is the arbitrator between the other two parties, and, by logical reasoning, is as much the servant of one party as of the other, in deciding disputes between them. What an absurdity this is; it violates the first principles of arbitration, that an arbitrator shall not be interested with either party to the dispute, and it places the engineer in a position which as an honest and well-intending man he ought not to be willing to accept. It is asking too much of him, that, having contracted to give his time and energy and zeal for a consideration, to his employer, he should be expected to act as an arbitrator in matters where his employer's interests are concerned. The writer has on occasion served as an arbitrator in a controversy involving claims by a contractor which were resisted by the engineer, and in this instance the engineer took the honorable position that he ought not to be required to arbitrate a dispute in which he was one of the parties, and asked for the appointment of arbitrators. It is possible that if experienced and reputable contractors were called to testify in this matter and were willing to give away their "trade secrets" they would agree that from their standpoint satisfactory contracts are such as are carried on under the direction of satisfactory engineers. Some contractors confine their work to railroad construction, feeling that as a rule they will be under the direction of experienced and fair engineers, and if this should not happen to be the case, there is usually a general manager, vice-president, or some other official, who will interest himself to see that a just settlement is made. It has been said of some railroad contractors that they pay no attention to the contract, feeling that if it is literally construed, they have no case in time of trouble, and yet they are willing to undertake the work in the confidence that the railroad company will, in the end, give them a fair settlement. Surely, nothing short of implicit, childlike confidence in the engineer and his employer, would warrant a contractor in subscribing to a contract containing the stipulation quoted below, which

is copied from a printed form of contract issued by one of our principal railway systems:

"Engineer of Construction appointed umpire:

It is mutually covenanted and agreed by and between the said parties hereto, that, to prevent disputes or misunderstandings between them in relation to any of the stipulations and provisions contained in this agreement, or as to the true intent and meaning thereof and of the specifications hereunto attached, and of the plans or as to the matter of performance of said contract by either of said parties, and for the speedy settlement of such disputes as may occur, the Engineer of the Company who may be such at the time of making the final estimate, shall be and he is hereby made, constituted and appointed the sole arbitrator to finally decide all such questions and matters; and said Engineer shall also determine, and set forth in the final estimate, the quantity, character, kind, and classification of all work performed and materials furnished by the Contractor under this contract, including all extra work and materials; and his decision and determination as to any and all such questions, matters and things, and not constituting any of the terms and provisions, of this contract, shall have the force and effect of an award between the Contractor and the Company, and shall be final, binding and conclusive to all intents and purposes, and at all times and places upon the said parties hereto.

And the Contractor hereby waives all objections to the appointment of said Engineer as sole arbitrator as aforesaid, by reason of his being a stockholder, director, officer, agent or employe."

Such stipulations are not confined to railroad contracts. They are present in all kinds of construction contracts, and notably so in government contracts. It is claimed by some that a contractor cannot, by contract, relinquish his rights as a citizen and that he can still appeal to the law. If this be so, he is nevertheless at a disadvantage and will suffer much before making that appeal, and if he has a government contract he is calmly informed that the government cannot be sued and asked what he is going to do about it.

It is well known to experienced engineers that it is next to impossible to describe and define the work done and materials used under construction contracts, so completely as to avoid questions which must be decided by the application of judgment and reason, and that arbitration is necessary to secure equity for the contracting parties. If this be granted, who shall be the arbitrator? The engineer in the employment of one of the parties is, by virtue of his employment, incompetent to be that arbitrator,

and ought not to be expected, or be required, or attempt to be such an arbitrator. Disputes between the engineer and the contractor may properly be submitted to arbitration.

The writer has long been of the opinion that clauses in construction contracts which name the engineer of one of the parties as an arbitrator, should be eliminated, and replaced by others providing for arbitration by a disinterested party.

ARBITRATOR'S FEES AND EXPENSES.

When the submission does not provide for the fees and expenses of the arbitrators, it is customary for the arbitrators to include these in their award, in which case they reimburse themselves for expenses incurred, and fix the amount of remuneration for their services, and then determine in what proportion these amounts shall be divided among the parties who signed the submission.

The writer believes that the fees of arbitrators should be a matter of agreement, and fixed before the arbitrators accept their appointment, that the contestants should agree in advance, that each shall bear an equal share of these fees and expenses and that this agreement should be clearly expressed in the submission.

CONCLUSION.

It is not so much the purpose of this incomplete discourse on arbitration to furnish a manual for the conduct of arbitration cases, as it is to call the attention of engineers to this method of settling disputes incidental to their practice. It is the writer's desire to interest his brethren in the subject, to invite their criticism, and to provoke them to discussion, to the end that the method may receive their due consideration, and that such merit as it contains may be applied in practice. The writer is not aware of any authoritative treatise on the subject. Its importance has always been recognized by engineers but the application of it has been faulty being generally limited to the effort to make each engineer his own arbitrator. The writer believes there exists an opportunity for engineers to reform their practice in this respect, and that in any case, if arbitration is to be resorted to there should be established a recognized code for its conduct, and that this code should be made by engineers on their own motion.

DISCUSSION.

W. W. Curtis, M. W. S. E. (Chairman): Mr. Bates has called our attention to a matter of very great importance and to one which has great possibilities. The paper is timely and is so complete in its matter and so excellent in its manner of presentation, that any material discussion of it is somewhat difficult. All that one can

hope to do is to perhaps reinforce some of the author's conclusions, both as to desirability of arbitration and as to methods to make such effective.

As long as human nature is as it is and man is afflicted with the greed for more, and with infirmities of judgment, there will be disputes which can only be settled with essential fairness by a submission of the questions to parties having no interest in the matter.

I think there is no room for argument on the proposition that any one who is to act as a judge between two parties should be one without any interest, direct or indirect, in the matter, and whose relations with both of the parties to the dispute are such that there will be no bias, or prejudice, to prevent considering the matter entirely on its merits and rendering a judgment which shall be based only upon the facts.

To leave the determination of such questions to a man who has been in direct contact with the subject, regarding which the dispute has arisen, is so manifestly unfair it is somewhat surprising that it is ever done; and it is certainly a tribute to the desire for justice, both of engineers and of contractors, that such a method has become general and has given as large a measure of satisfaction, as is the case.

I recognize fully that contractors have acceded to such conditions often through necessity and not through their own volition; but if the results of such methods had not generally proved satisfactory, or, at least, measurably satisfactory, the custom could not have become as general as it has.

A man does not insure his property from fire, however, because of the universality of fires; nor do we police our cities because all men are criminals. It is to protect one's self against the exception, that insurance, police, and a great many of the things which we consider necessities for the safety and happiness of man, exist. For the same reason, the conditions in the contract making the engineer the sole judge, both as to facts and equities, should be abolished and provision made for the determination of such questions by unbiased and impartial persons.

The desire of every honest man is to pay for what he gets and to get what he pays for; and to both pay and get at the specified time. At present, in case of disputes arising in the course of business, the usual resource is to the courts, and generally the state courts will be the only ones which have jurisdiction. It is possible to submit such cases either to a jury, or to the court, for determination; but in either case the results are likely to be unsatisfactory. Of the two, the submission to the court is more likely to produce substantial justice, and at first thought it would appear that the man who insists upon a jury trial would not be likely to agree to the submission of his case to arbitration, but this does not necessarily follow. One may be entirely willing to have his case deter-

mined on its merits without any effort to benefit his own cause through the sympathies, or prejudices of the jury, and still be entirely unwilling to submit the matter to the court. Judges are, in all essential respects, human, and are somewhat prone to become inflated with a sense of their own importance and to credit themselves with a higher degree of perspicacity than the facts warrant. This sometimes leads them to be impatient and unwilling to listen to a full and complete presentation of the facts necessary for an understanding of the case. Then, too, the courts are quite generally behind on their calendars and it is necessary that the hearing of cases be expedited, so that unless the case happens to be some celebrated scandal, or a matter of politics, the disposition is to cause the "steam-roller" to operate, sometimes to the injustice of litigants.

To submit such cases as Mr. Bates has particularly in mind, and for which he advocates arbitration, to the jury of the usual character, is more or less of a joke and a very bad joke at that.

To listen to the presentation to a jury of twelve men, none of whom perhaps ever owned one thousand dollars' worth of property, of a case involving long and intricate accounting, or the determination of facts requiring expert knowledge to understand and to appraise at their proper values, is to realize at once the utter absurdity of our jury system when applied to such matters.

Another difficulty with recourse to the law for the determination of such questions is the expense and loss of time which necessarily follows. The mere court costs represent but a small portion of the expense of such litigation; and it does not necessarily follow that the attorneys' fees would be less with the submission of such matters to arbitration.

The uncertainties as to the date of hearing before a court and the necessity for having witnesses present and waiting upon the convenience of the court, is a serious item. With the method of arbitration, definite engagements can be made with the assurance that the matter will be heard on the specified dates. With a court this is absolutely impossible.

Then with an arbitration, a judgment is conclusive, or provision can, and generally will, be made for its conclusiveness.

With a court, or jury trial, however, it is a very exceptional case to have litigants agree in advance that the verdict of the lower court shall be accepted without appeal; and the moment an appeal is taken, the possibilities for further delays are immense. With the condition which exists in the city of Chicago, it takes about two years for a case to reach the Appellate Court, while in other parts of the state it takes from six months to a year.

There is also the possibility of a further appeal to the Supreme Court.

I think there is no question but what recourse to arbitration offers the best promise of an early and a complete determination of justice in any dispute, based upon the interpretation of a con-

tract; and the probable reason for the limited use which has been made of this method is the failure to apprehend the possibilities of it, a lack of familiarity with it, and the absence of any formulated rules to guide in the preparation and prosecution of an arbitration. One of the most common objections to submitting a cause to arbitration is the feeling that it will result in nothing but a compromise verdict. Even if this were true it would not necessarily be any criticism on the wisdom of submitting matters to arbitration, because it is rare that in a dispute either party is entirely free from criticism, and it is very apt to be the case that any just decision will not give either party all that is claimed. Juries and courts, too, are not free from a disposition to split the difference; and with less ability to estimate the materiality of the concessions which may have been made already.

I think, however, the real basis for criticism against the method of arbitrating difficulties, as usually practiced, is due to the method of selecting arbitrators; and the recognition that as long as such a method is followed there are not three arbitrators, but in reality only one. The method of each party to a dispute selecting an arbitrator, and these two agreeing upon a third, is entirely wrong, and I am glad to see that the author condemns it. It is perfectly proper for one to serve on an arbitration board, even when selected in this manner, if the actual conditions are recognized, but the method is wrong and should be corrected. Each one of the arbitrators should represent each of the disputants, or neither, as you may prefer to put it. Just how the three arbitrators should be selected so that they may each feel that they are the representatives of both parties to the case, is perhaps not easily determined, but the problem is certainly possible of solution, and I believe this idea of having none of the arbitrators selected by one only of the parties to the dispute should be considered as fundamental.

The greatest advantage, it seems to me, in the settlement of disputes by arbitration, lies in the ability to secure competent judges to pass upon the matter. The author has well expressed the difficulty which may exist, if the arbitrators are men who are too familiar with the class of work which is the subject matter of the dispute. It is very much better to select those who have a general knowledge of the subject, to whom the presentation of the case by the litigants will be intelligible and who can understand and appreciate at its full value any evidence which may be given by others who are expert in that particular branch.

The fact that the arbitrators are not bound by the strict rules of law and evidence, I presume may be an advantage; although my own opinion is that these rules when administered by an intelligent judge are sufficient to permit of the introduction of all material facts. As a matter of fact, it will be rare when parties will submit to arbitration claims which have not a clear legal basis, as well as an equitable basis. The great difficulty when one departs from

the ordinary rules of evidence, is that the door is open to all kinds of immaterial matter, so that the real facts pertinent to the case may be lost in the mass of immaterial and irrelevant matter. Possibly I do not appreciate the full force of this feature, because while my practice in the last few years has been very largely in connection with litigated matters, most of it has been in equity proceedings, where there is more latitude allowed in the development of the facts than is the case with the other branches of the law. My own feeling is that a reasonably close adherence to the rules which have been evolved in the practice of law would constitute the wise and safe course for the practice of arbitration. It is when these rules are interpreted by partisan judges, or those having an undue sense of their own importance, that they become an obstruction to the course of justice.

Mr. Bates has done a great service in calling attention to this matter and in placing on record so much information relative to the details of arbitration, making it possible for others to find a starting point from which to prepare for the settlement of their disputes in this way.

I had one of my friends, who is an attorney, read over my notes, and he asked me whether the Society proposed selecting or appointing a board of arbitration. I told him I did not think this Society had any idea of that; in fact, that I thought it was beyond the powers of the Society to take such action under our Constitution. As I look at this paper, it is educative; that is the intent, I think, of the writer of the paper; and in codifying the facts and the rules which have been evolved elsewhere and bringing these to our notice, putting them where we can find them, and giving us the line along which we can pursue the matter to get other and fuller information, he has done a great service, and we certainly owe him our thanks.

William B. Jackson, M. W. S. E.: I have read Mr. Bates' paper with more than ordinary interest and it seems to me that it is, from every point of view, admirable. I believe that all of you must agree with me in this. It was high time that some engineer, of the widely recognized standing of Mr. Bates, should present to this Society a paper of the character we have before us.

There is a bit of quiet humor in the first paragraph of the paper, wherein the author says: "Of course parties ought not to disagree; this is inexcusable, and yet they will sometimes disagree and there is no immunity from disputes in this unregenerate world." But, gentlemen, when it comes down to the facts, we all know that human beings are bound to disagree; and we must recognize that this would be a humdrum old world if such were not the case. But taking human beings as they are, the question is, how are we going to settle these disputes with the greatest net fairness to all concerned, and with the least antagonism engendered between the parties to the contest?

We must all admit, however, that the author has presented, in this paper, an admirable example of a case where it is not possible to raise a serious disagreement.

Correctly conceived arbitrations are, I believe, appropriate means for deciding disputes, but improperly conceived arbitrations are worse than nothing, and the author has unquestionably laid before us, in admirable form, essentials which must be observed in inaugurating acceptable arbitrations.

Mr. Bates discusses briefly the relations of arbitrations to courts. We must appreciate that there are bound to be cases which have been carefully considered by arbitration boards which finally get to the courts, but such cases, if considered by properly constituted boards of arbitration, go to the courts with the questions of fact, at least, intelligently and thoroughly threshed out, so that there is presented for the court's consideration a well worked out problem, which is not the case in many, especially engineering, problems which go to the courts and wherein there is frequently an astounding nebulosity.

The author has well pointed out the need for clear, definite understanding of the terms of the arbitration, and an appreciation of the dignity and an understanding of the responsibilities involved. It is seldom, in my opinion, that arbitrators appreciate—at least in arbitrations affecting less important interests—the real responsibility or dignity of the position. Arbitrators are prone to forget that on their work is to be based the fair division of property and of rights as between their fellow men,—one of the most important factors in human life.

Under the heading, "Number of Arbitrators," the method of choosing arbitrators is given consideration, and we must appreciate that the proper method of choosing arbitrators, as the author has pointed out, is an extremely important one. Under the method which he has designated as objectionable, it is seldom that the "original" arbitrators appreciate that they must in fairness not be special pleaders for either side, but that they should be arbitrators under the strict interpretation of that word. The fact that he is an arbitrator and not an advocate must always be borne in mind. It is very difficult to find two men who are appointed by opposite sides of a controversy who are able to be true arbitrators. It is not uncommon for one of the "original" arbitrators to present his side of the case fairly and reasonably, and for the other "original" arbitrator to present his case from the standpoint of a trader, thus placing the third arbitrator in an unfair position, wherein he has to appear, to the ordinary observer, as a partisan to one side of the controversy, if he is going to render a just decision. In other words, the only position which he can with propriety and honesty take is to uphold the original arbitrator who has given a fair statement of the case, and everything that he does must be in line with

breaking down the argument of the other arbitrator. Also, under such conditions, instead of the fair responsibility for honestly arbitrating the question at issue being divided amongst the three arbitrators, the entire responsibility is thrown upon the third, as our chairman has clearly explained.

Referring to the heading, "Cases Which May be Arbitrated," I believe that this question of the insertion of iniquitous requirements in contracts is of sufficient importance to be the basis in itself for a paper by such a man as Mr. Bates, and I wish it might be the basis of a paper for this Society. I dare say that few contractors sign the usual form of contract without a mental reservation that the engineer shall be the sole judge only in cases where the latter's judgment reasonably coincides with his own. There are innumerable instances where contracts are drawn, in which the signer is expected to agree to matters directly contrary to the facts. As a homely illustration of this, let us consider the contracts that we are often asked to sign for our office space or for our apartments, wherein we are expected to sign a contract stating that we agree that the quarters are complete in every detail, and are satisfactory to the prospective tenant, although the premises may be in a most chaotic or unfinished condition. When we decline to sign such a contract, the person who brings the contract to us usually considers us a little queer. All such conditions lead to winking at dishonesty, and to a lack of appreciation of the need for scrupulous honesty in engineering and other business undertakings. Such conditions are common in engineering contracts, and are especially common in contracts with the Government and States. Contractors and all of us are expected to submit to evident dishonesties which we are told are merely forms. But I believe that so long as we tolerate dishonest forms in contracts, there will be a tendency toward dishonesty amongst those who have to do with such contracts.

I feel that we all should cordially thank Mr. Bates for presenting to us in such clear fashion the need for bringing our arbitration methods, and our contract forms, into conformity with strict honesty.

T. L. Condron, M. W. S. E.: In connection with Mr. Bates' very interesting and instructive paper, I present for consideration certain paragraphs from the "General Conditions of the Contract," of the "Illinois Building Contract Documents," in the preparation of which a committee of this Society co-operated with similar committees from the Illinois Chapter of the American Institute of Architects, The Chicago Architects' Business Association, and several of the local associations of contractors and manufacturers engaged in the building industry.

In June, 1910, President Alvord of this Society appointed Messrs. Giaver, Ritter, Shields, Warren, and the writer, as a com-

mittee to confer with similar committees from the above named associations for the preparation of a uniform contract. After several sessions of this general committee, the first draft of the proposed uniform contract form was referred to a sub-committee* consisting of two members each from the two architectural associations, the Western Society of Engineers and the contractors' associations, this committee being so constituted that there would be an equal number of professional and non-professional members, while the chairman of the general committee, Mr. H. B. Wheelock, architect, was made chairman of the special committee for the final revision of the proposed contract form. This special committee was appointed in September, 1910, and continued its labors until June, 1911. The final draft of the contract documents was submitted to and revised by the general committee, after having been formally submitted to Messrs. John P. Wilson and H. L. Burnham, attorneys having wide experience with building contracts in this State. The criticisms and recommendations of these attorneys were followed in the final revision of these contract documents. The final editing of the documents was left to a sub-committee on which the writer served as the representative of this Society.

These "Illinois Building Contract Documents" cover seventeen pages of ordinary letter size, printed in clear, bold type, and are divided as follows:

Invitations to Bid.
Proposal.
Articles of Agreement.
Bond.
General Conditions of the Contract.

These documents are published by the Chicago Architects' Business Association, and may be obtained at the offices of that association for a nominal charge, which covers the cost of printing.

I call your attention to the documents in general, as I believe that they mark an important step in the direction of a clear and fair contract form. It should be stated, in this connection, that the American Institute of Architects started work in this direction long before the forming of this local committee, and the preliminary work of the Institute was used as a basis for the work of this particular committee. While a number of changes were made from the preliminary form of the Institute's draft, such changes were made only after very careful consideration and discussion, and it was intended that the documents adopted by the local organizations would have a more or less local character.

The "Illinois Building Contract Documents" have been adopted

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*Messrs. Pond, Llewellyn, Mundie and Hall, architects; Giaver and Condron, engineers; Lanquist, Wells, Falkenau Bernard, Miller and Orr, contractors.

and recommended for use by the Illinois Chapter of the American Institute of Architects, The Chicago Architects' Business Association, The Western Society of Engineers, the masons, carpenters, architectural iron, cut stone, sheet metal, and other contractors' associations of Chicago.

I give below in full the paragraphs on the subject of arbitration which form a part of the "General Conditions of the Contract," as they are printed in that document, but do not give them in the order in which they appear, having changed the order to present the matter clearly in connection with the discussion of Mr. Bates' paper. All of these paragraphs received most careful consideration from both the architect's and engineer's points of view and the contractor's point of view; and the review of the several paragraphs by attorneys well qualified to pass upon the legal points would seem to insure that all of these paragraphs deserve favorable consideration by the members of this Society when called upon to prepare contracts governing the execution of engineering work. It is, of course, a simple matter to read into the paragraphs the word "engineer" where the word "architect" appears, for the relations of the engineer to his work are usually the same as those of the architect to building construction.

The following paragraphs are selected from the "documents," as having a direct bearing on the subject under discussion:

(35) Architect's Status.

The parties to the contract recognize the Architect as the interpreter of the drawings and specifications which are part of the contract documents, and in that capacity he is to define their true intent and meaning. He is not the agent of the Owner, except in structural emergencies (Section 37), and except when in special instances he is authorized by the Owner so to act.

(36) Architect's Notifications.

The Architect will notify the Contractor of the rejection of faulty work on discovery, but his failure to detect omissions from or violations of the contract shall not operate as a waiver of the Owner's right growing out of defects in work or material. It is not incumbent upon the Architect to notify the Contractor when to begin, to cease, or to resume work.

(37) Architect's Authority in Emergencies.

The Architect has authority to stop the progress of the work whenever, in his opinion, such stoppage may be necessary to insure the proper execution of the contract. In an emergency affecting the safety of life or of the structure or of adjoining property, he has authority to make such changes or to order such work, extra to the contract or otherwise, as may in his opinion be necessary.

(33) Cases Subject to Arbitration.

The final decision of all questions arising under this contract shall be made and given by the Architect, and both the Owner and the Contractor hereby agree to be bound thereby, and such decision shall be a condition precedent to any right or legal action by either Owner or Contractor, save only in the following cases, in which, in the event of dissent by either party from the decision of the Architect, the question shall be arbitrated in the manner provided in Sec. 34.

a. Condemnation, Sec. 16.
b. Certificates not final evidence, Sec. 21.
c. Deduction for defective work, Sec. 22.
d. Contractor's claim for extra Remuneration, Sec. 24.
e. Additions and Deductions, Sec. 25, a, b and d.
f. Contractor's Liability for Delay in Completion, Sec. 28.
g. Contractor's Claim for Extension of Time, Sec. 29.
h. Contractor's Claim for Damages, Sec. 30.
i. Mutual Responsibility of Contractors, Sec. 31.
j. Owner's Right to Terminate and Complete Contract, Sec. 40.

(34) Method of Arbitration.

In any of the above named cases, the Owner or the Contractor may demand arbitration, by filing with the Architect within ten days of the receipt of the decision from which he appeals, a written notice of such demand, sending at the same time a copy thereof to the other party to the contract. In case no such notice be filed within ten days, both parties shall lose the right of arbitration and the decision of the Architect shall stand as final.

In case such notice be filed the difference or dispute shall be submitted for arbitration to three disinterested arbitrators of whom or in case of his inability or refusal to act shall be one, and of the other two, one shall be chosen by the Contractor and one by the Owner.

It will be noted that this plan differs from the one more commonly followed, for it provides that the arbitration board shall consist of one representative of the owner and one of the contractor, and an umpire, selected at the time of the signing of the contract, before any dispute has arisen.

(34 Continued.)

Should the party filing notice fail to choose an arbitrator within ten days of filing such notice, his right to arbitration shall lapse, and the decision of the Architect shall stand as final. Should the other party fail to choose an arbitrator within ten days of the filing of the notice, then the Architect shall appoint an arbitrator who shall act with the other arbitrators. Should either party refuse or neglect to supply the arbitrators with any papers or information considered necessary by them and demanded in writing, the arbitrators are empowered by both parties to take *ex parte* proceedings.

The arbitrators shall act with promptness. The written decision of any two of them shall be binding on both parties hereto. The decision of the arbitrators upon any question subject to arbitration under Section 33, shall be a condition precedent to any right of legal action by either Owner or Contractor.

The arbitrators if they deem that the case demands it, are authorized to award to the party whose contention is sustained, such sum as they shall deem proper for the time, expense and trouble incident to the arbitration, and this sum may be named in cases where the claim is set aside in whole, or as an addition to or deduction from the amount of the principal award. The arbitrators shall assess the costs and charges of the arbitration upon either or both parties, in such proportion as the arbitrators shall deem just.

In lieu of the three arbitrators hereinbefore provided for, the parties may by mutual agreement name a single arbitrator, and in such cases the provision of this section shall otherwise apply.

June, 1912

The following are the clauses in the contract that are subject to arbitration:

(15) Re-examination.

When required, the Contractor shall provide all facilities and labor necessary for a complete re-examination of work under suspicion, and if the work is found defective, the Contractor shall bear the expense of re-examination and replacement. If not found defective, such expense shall be credited to the Contractor as extra work, as provided in Sec. 25.

(16) Condemnation and Correction of Defective Work.

The Contractor upon receiving from the Architect written notice and within such reasonable time as may be named therein, shall remove from the premises all materials, whether worked or unworked, and take down and remove all portions of the work condemned by the Architect as unsound or improper or as in any way failing to conform to the contract; and the Contractor shall bear the expense of making good all work destroyed or damaged by such removal, and shall promptly replace and re-execute his own work in accordance with the contract and without expense to the Owner.

If the Contractor does not remove such condemned or rejected work and materials within the time limited by the notice, the Owner may remove them and may store the materials at the expense of the Contractor. If the Contractor does not within ten days after such removal by the Owner pay the expense of such removal, the Owner may, upon ten days' written notice sent by mail to the Contractor at his place of business, sell such materials at auction or at private sale. Such notice may be sent to the Contractor at any time after such removal. The Owner shall account to the Contractor for the proceeds of such sale, after deducting all expense of removal and storage. (See Sec. 33.)

(21) Certificates Not Final Evidence.

No certificates given, except the Final Certificate, nor payment made under the Contract, nor partial or entire occupancy of the premises by the Owner shall be construed as an acceptance of defective work, or of improper materials, or as condoning any omission. No payment nor certificate, final or otherwise, shall be construed as relieving the Contractor from his obligations to make good any defects or consequences thereof, discovered in his work after completion and acceptance of the same, other than those due to accident, abuse, or wear and tear, nor as a waiver of any specific obligation the Contractor may have assumed as to the durability of his work. (Subject to arbitration.)

(22) Deductions for Defective Work.

If, in the opinion of the Architect, it is not expedient to correct injured work, or work not done in accordance with the contract, the Owner may deduct the difference in value between the work involved and that called for by the contract, together with a fair allowance for damage, the amount of which shall be determined by the Architect. (See Sec. 33.)

(23) Changes in Work.

The owner may, without invalidating the contract, make changes by altering, adding to or deducting from the work, provided however, that such changes shall not exceed 5 per cent of the value of the contract where work is let on a general contract, or 10 per cent of the value of any single branch or trade included in a general contract, except by mutual consent. No claim for extra charge for such changes shall be valid unless such work is done in pursuance of a written order therefor, from the Architect acting under the authorization of the Owner; unless otherwise expressly agreed,

all such work shall be executed under the conditions of the original contract. (See Sections 25 and 30.)

(24) Contractor's Claim for Remuneration.

Should the Contractor deem any work which he is called upon to perform, whether by instructions, by detail drawing or otherwise, to be extra to the contract, he shall notify the Architect before proceeding to execute it. Should the Architect decide that no extra is payable, and order the Contractor to proceed, then the Contractor shall do so, and the question whether there is an extra and, if so, its amount, shall be subject to arbitration.

(25) Additions and Deductions.

Should it be claimed by either of the parties hereto that any alterations in, additions to, or deductions from, the work covered by the contract affect the contract price, then its value shall be determined in one of the following ways, as may be mutually agreed upon or arbitrated:

a. By unit prices named in the contract or subsequently agreed upon, in which case the Architect shall make the award, subject to arbitration.

b. By cost and percentage, in which case the Contractor shall keep a true and correct account of the net cost of labor and materials, rendering to the Architect, at required intervals, detailed statements and vouchers, and the Architect shall award an amount as cost and profit, subject to arbitration.

c. By estimate and acceptance in a lump sum.

Payments for all extra or additional work and deductions from work omitted, shall be adjudicated and settled for every thirty days.

d. In case an agreement as to price cannot be reached, the Architect may, with the authority of the Owner, order the work to proceed, and the Contractor shall forthwith proceed and leave the price to be settled by arbitration.

(28) Contractor's Liability for Delay in Completion.

Should the Owner claim damages for delay in the completion of the work, the Architect, if, in his opinion, any damages have justly accrued, shall make his award, and shall write the amount thereof across the face of the final certificate as "amount to be deducted from the face hereof for delay in completion of the work." (See Sec. 33.) Thereupon the Architect's services in this matter shall terminate, except as provided under Sec. 34.

(29) Contractor's Claim for Extension of Time.

Should the Contractor be delayed in the prosecution or completion of the work by the act, neglect or default of the Owner, or of anyone employed by the Owner, or by any damage caused by fire or other casualty, for which the Contractor is not responsible, or by strikes or lockouts, or for any other reason deemed sufficient by the Architect, then the time fixed in the agreement for the completion of the work shall be extended for a period equivalent to the time lost by reason of any and all the causes aforesaid. Such extension of time shall be determined and fixed by the Architect (See Section 33), but no such allowance shall be made unless a claim therefor is presented in writing to the Architect within forty-eight hours of the occurrence of such delay.

(30) Contractor's Claim for Damages.

Should the Contractor claim to be damaged by any act or omission of the Owner or Architect, relating to this contract or to the work, the right of the Contractor to compensation for the damage suffered and the amount of such compensation shall be determined and awarded by the Architect

(subject to arbitration); but no such allowance shall be made unless a claim therefor is presented in writing to the Architect within ten days of the occurrence of such damage.

(31) Mutual Responsibility of Contractors.

Should the Contractor claim to be damaged by the act, neglect or default of any other Contractor employed by the Owner upon the work, then the Contractor shall make his claim in writing against the Owner through the Architect at his office, or his representative upon the work within forty-eight hours. The Architect upon request shall adjudicate claims made under this section and certify to the Owner accordingly.

(40) Owner's Right to Terminate and Complete Contract.

Should the Contractor become insolvent, or at any time refuse or neglect to supply a sufficiency of properly skilled workmen or of materials of the proper quality, except in case of strikes or lockouts, or fail in the performance of any of his obligations under this contract, such refusal, neglect or failure being certified to by the Architect as sufficient ground for such action, then the Owner after forty-eight hours' written notice served personally upon the Contractor, or delivered at his last known address, may terminate the employment of the Contractor for said work, and for the purpose of completing the work, may enter upon the premises and take possession thereof, and of all materials, tools and appliances thereon, and may employ any other person or persons to finish the work and may provide the materials therefor, or may re-let same by contract. In case of such discontinuance of the employment of the Contractor, he shall not be entitled to receive any further payment until the said work shall be wholly finished, at which time, if the unpaid balance of the amount to be paid shall exceed the expense incurred by the Owner in finishing the work, including proper compensation to the Architect for his additional services in connection therewith, such excess shall be paid by the Owner to the Contractor. But if such expense shall exceed such unpaid balance, the Contractor shall pay the difference to the owner. The expense incurred by the Owner as herein provided, either for furnishing materials or for finishing the work, and any damage incurred through such default, shall be audited and certified monthly by the Architect, subject to arbitration within ten days.

(45) Sub-Contracts.

The Contractor shall not assign this contract nor sub-let any portion of the work without the approval of the Architect, but such approval shall not relieve the Contractor of responsibility for his sub-contractors. The Contractor in sub-letting any part of the work to be done under this contract shall make with the sub-contractor a contract by which the sub-contractor shall expressly agree to be bound by the General Conditions of the Contract so far as they are applicable.

It will be seen that in these documents the architect is recognized as the interpreter of the drawings and specifications, and in that capacity he is to define their true intent and meaning. It is stated: "He is not the agent of the owner, except in structural emergencies and except when in special instances he is authorized by the owner so to act." This is contrary to the view expressed by Mr. Bates as to the proper relations of the engineer to his principal and to the contractor. Personally, I quite agree with Mr. Bates' view, as it has often seemed to me unreasonable for the engineer to be considered an impartial interpreter of his own plans

and specifications, no matter how fair-minded he may be, and while in ordinary cases his interpretation of these plans and specifications should be accepted and followed, there are sure to be times when it will be impossible for the engineer to settle disputes and differences which may arise with equal fairness to his principal and the contractor. If the engineer realizes, in drawing up his contracts and specifications, that for a certainty disputes and differences will be referred to a disinterested umpire or to arbitration, he will be all the more careful to so write his contracts that a settlement of such differences will not be likely to react unfavorably on him, and by the use of that very care may save his employer being dragged into a dispute with the contractor.

Such papers as the one before us will do much to promote a wider adoption of these principles of reform, which the author recommends, and we may confidently hope they may start the movement which he suggests towards an adequate code for arbitration in connection with engineering contracts.

M. K. Trumbull, M. W. S. E.: Mr. Bates' paper on arbitration is most dignified and convincing. He has honored this Society in offering its introduction to us. There is no association or magazine in the world that would not have been glad to have the privilege of its first presentation.

It reflects the practical wisdom and idealism of the writer and the orderly manner in which he approaches every subject. It might be argued that the treatment of the subject is too brief. Upon reflection, however, the conclusion is reached that the purpose of the paper is admirably brought out.

It is to be hoped that the author when convinced of the cordial reception this abstract has received and is destined to receive when given wider circulation than is possible this evening, will offer to the public a treatise that would unquestionably be an authority on the subject of arbitration.

The principle of law is common sense and equity. In arbitration, as presented by the author, we realize what law attempts to accomplish and that, in the majority of cases, decisions by and settlements through the instrumentality of boards of arbitration are arrived at more speedily and the ponderous procedure of courts of law is eliminated. Mr. Bates' advocacy of compromise is bold but convincing. Personally I would like to have him expand upon the legal effect that may be given to a decision of a board of arbitration, and as to whether one of the individuals, making a submission to such a board, can withdraw before the award is made. Moreover, I would ask if, in his opinion, there should be an enforcement of the award by statute.

One is disposed, in reading Mr. Bates' article, to ask if he holds that a Government contractor has no relief against unjust decisions on the part of the engineer in charge of the work.

C. F. Loweth, M. W. S. E.: The speaker hesitates to attempt a discussion of this paper. Since the advance copy came to his hand he has been so busy that he has not had time to more than casually look it over.

Some engineering specifications have contained clauses that have outgrown their usefulness and become obsolete on account of the advance of the art along that line of construction, and this has come about by reason of the fact that engineers, in writing specifications, have sometimes copied older specifications, and appear to have been slow to discard anything in the old, and have frequently added a little something new of their own. So it has come about that many specifications have contained old and outgrown requirements more or less meaningless, useless, or even harmful.

The speaker thinks that much the same applies to many engineering contracts. When a new contract is to be drawn, for one reason or another, the old ones are more or less copied, and some of the old, outgrown requirements are perpetuated, modified, perhaps, so as to make them even more useless or harmful. Such methods are wrong, and undoubtedly the paper of the evening will call attention to the matter, and tend to bring about more consideration and care in writing engineering specifications and contracts.

Arbitration is better than litigation; but if the parties to an agreement have so clear a comprehension of their several rights and responsibilities, that arbitration is unnecessary, this is still better. The speaker thinks that the responsibility for bringing about such a clear understanding between the parties rests very largely with the engineer. If he has, as he should have, a good general knowledge of the law of contracts, and a goodly degree of business sense, coupled with a large sense of fairness, he can, in many cases, be trusted to draw up a form of engineering contract which will be alike fair to all parties concerned, and doubtless permit of the work being satisfactorily prosecuted, completed, accepted, and paid for, without misunderstanding or dissatisfaction on either side. If the engineer can do this it would appear desirable from every point of view.

Engineers have been more or less accustomed and trained to act as arbitrators during the execution of engineering contracts. It seems necessary that this should be the case; and if they have sometimes failed in this qualification, as no doubt they have, then the fact bespeaks the need of more care in their education and training, and the need of cultivating a larger sense of business fairness and equity, and the cultivation of those qualities whereby a man acquires convictions of the right kind, and the necessary courage to live up to them.

In arbitrations it will always be more or less difficult to pick men who will be arbitrators in the true sense of the word, and not partisans. In many cases the arbitrators chosen by the several parties are more largely advocates, and the only arbitrator is the

odd party. This should not be so, but it is human nature and is difficult to avoid, and especially so if, as one of the speakers has pointed out, one man on an arbitration board forgets his responsibility and becomes an advocate.

The speaker is glad this paper has been presented; it cannot help but disseminate much good, not only among the engineering profession, but generally.

Wilson E. Symons, M. W. S. E.: This paper is too thorough in every respect for me to attempt to add anything to it, or even to discuss any of the points presented by the author. There are one or two angles or phases of the question, however, on which I beg to intrude a few remarks.

I will ask if the author, in his closure, will not kindly refer to the legal questions in connection with the subject of arbitration, or the effect on the profession of law, by a more general resort to arbitration in adjusting disputes.

The principles of arbitration, it may be said, go back to biblical times. About the first declaration of those principles came from the lowly Nazarene, when he said, "On earth peace, good will toward men." That was supplemented by the Apostle Paul, when he said, "Come, let us reason together." But we have not been living in that state of brotherly love and perfect agreement to which we were admonished; neither have we at all times reasoned together. It seems that as the world gets larger we get farther apart on many things. The term "success in life" is not infrequently spelled with a capital *S,* and this letter *S* is crossed by two vertical bars, making of it the dollar mark, and as interpreted by many people its real meaning may be said to represent the amount of money possible to get and keep out of jail with. So long as that spirit exists, either between individuals or corporations, there will be more work for the lawyers and our courts, and less work for arbitrators. I think it would be a blessing to the country if the amount or volume of business now taken to the courts could be reduced, and the amount handled by arbitrators increased. The thought has occurred to me, in connection with this valuable paper, that it may be the nucleus to a new thought or creed that has not heretofore been presented to thinking people as it should have been.

We speak with much pride of the freedom in our institutions,—freedom of individual thought and action,—while as a matter of fact we do very little, if any, of our thinking in some things. In most of our business transactions it is almost all delegated to lawyers. The words of the martyr, Lincoln, might be paraphrased as follows: "This is a government of lawyers, by lawyers, and for lawyers."

Many of the contracts under which difficulties arise are drawn by lawyers who include clauses that lead to litigation rather than prevent it. We have, I believe, today in the city of Chicago about

6,000 lawyers. With a population of 2,250,000, this would be on about a basis of one lawyer to each 366 persons. Taking the average family one to five, it makes one lawyer to each 75 families. Now, we need *more good* lawyers, and we need less of the poor ones who foment trouble and make contracts and otherwise exercise their influence in a way that brings business to them and to the courts.

Our legislatures and our national law-making houses are almost entirely composed of lawyers,—not entirely, but a large percentage, —and as we are all the product of our environment, it is but natural to suppose that the result of the commercial relations between individuals and corporations, when measured by laws made by lawyers, will in a measure result in creating future business for them to handle. I think in the United States we have about 160,000 lawyers, and on a population basis of 91,000,000 there would be one lawyer to each 568 persons, or about one to each 113 families.

Viewing the situation from the foregoing standpoint, and the fact that we have about 114 professional law schools with an enrollment of about 20,000 new recruits coming on to do our thinking, talking, and quarreling for us, we could well accept and propagate this new gospel that Mr. Bates has brought so nicely and comprehensively before us, of providing means of settling many of these questions ourselves.

Why should men spend years to become engineers, contractors, or business men, and then, when it comes to the adjustment of any difficulty arising from their business relations, hire a lawyer to handle a matter well understood by the disputants, but which both the court and counsel frequently do not understand?

I have the greatest respect for our laws and those who are charged with their administration, but it seems to me that the principle set forth in this paper, particularly that feature which favors the adjustment of differences between individuals or corporations, by those who by occupation or profession are competent to judge as to the equities involved, should receive our most cordial support to the end that we may both individually and collectively preach the gospel of arbitration.

We should assume and maintain the position, never receding from it, that in handling any proposition entrusted to us up to the point of final settlement we should adjust ourselves to it, unless it be taken into court on legal points, or by means other than voluntary on our part.

We have in the United States about 68 schools teaching agriculture and mechanic arts, while there are 114 schools, with an enrollment of about 20,000, producing lawyers.

The paper is an excellent one, and one on which I certainly would not offer any criticism, but I am glad to give it my strongest endorsement, with the hope that it will result in being widely disseminated among public officers, business men, and the engineering

fraternity everywhere, to the end that more of the differences between engineers, railway men, commercial organizations and other persons between whom differences arise, will be settled by arbitration rather than by resort to the courts.

Alderman William J. Pringle: We are all good citizens engaged in business. That is, we ought to be. We all mean to be or should mean to be "on the square" with each other. The upright lawyer who deserves "standing" in the community ought to stand for the things that the last speaker has recommended. He ought to be a man who goes into court as a last resort. If he is loyal and faithful to his clients, he ought to advise them in such a way as to keep them out of court; and, if possible, to secure justice without going into court. There are all kinds of lawyers. We ought to eliminate the bad ones. Other professions probably suffer less from the advent of the shyster than does the law, but I suppose every profession has some of that element in it.

I could not help but recall, in listening, that in the history of jurisprudence, civilization long ago experienced some of the things that have been suggested and recommended here tonight. The fundamental idea that has been pointed out this evening has been that we should go backward until we reach a form of justice that is somewhat more simple in its methods than the forms that obtain at this time. If we go back to first principles or near first principles, we have a form of justice where the chief of the clan decided the disputes and questions arising among the people. He was a sort of "chief justice." If he was endowed with the judicial temperament, so much the better; if not, he meted out what he *called* justice. A little later we had a more democratic idea; here the issue was left to a vote of the clan,—the members of the clan,—and they decided as to what *they* thought was justice. We have now gotten far away from that idea. Some of our progressive political friends want to go back; I think you do.

It seems to me that an arbitration idea means about this, if pushed to a tangible and definite statement: that the machinery of the courts as we have the machinery at the present time, is somewhat cumbersome and fails, to a degree at least, to meet the exigencies of the cases as they present themselves from time to time. Of course, courts were formed originally to mete out justice, in these cases where disputes arise. Originally the courts were formed for the purpose of doing justice between disputants and to a large degree they have succeeded. To quite a degree they have failed. I believe that it would be an excellent thing if some legislation was had which would provide general boards of arbitration, quite a number of them, which boards could take up and deal with questions of the kind you are discussing, in a somewhat informal way. I cannot help but remember, in this connection, the way in which some of the cities and states of this country have

dealt with certain questions which have been troubling the people for a long time; certain questions which have been handled of late through what are called public service commissions, which are, in a sense, boards of arbitration. The Interstate Commerce Commission has some of the features of a public service commission. The public utility commissions of New York and Wisconsin have brought about desirable reforms; they have many arbitration features connected with their operation. Commission methods are substituted for cumbersome and tiresome court procedure; disputes are settled quickly and easily; disputes in which the methods employed by the courts have been somewhat too slow to satisfy the people, and with which the legislative and executive arms of the Government have found it difficult to deal intelligently and fairly. On these boards of arbitration, which have been recommended for the quick and efficient settlement of these disputes, we should have men of considerable expert ability, men who have a reputation for being able to be both honest and intelligent at the same time; we should have boards of this kind in increasing numbers. We need a public utilities commission in Chicago and in the state of Illinois, to deal with the many public utility matters that are crowding upon us here. We need, in the state of Illinois, to deal with these disputes that arise between contractors, more efficiently and quickly; the courts are too slow; the people hesitate somewhat before entering upon a period of prolonged litigation; we need bodies that will mete out justice more quickly.

It was suggested a number of times that there is a difference between a judge and an advocate. Now the board to which reference has been made a number of times in this discussion consists of two advocates, one for each party. Of course, if a man is an advocate, if he goes into court representing a client, it is his business to do the best he can for his client. If he does not, he would not retain the client. To hold his job he must represent his client and do the best he can for him. He is not a judge. He throws away part of his judicial spirit when he is employed by his client. He cannot be both a judge and an advocate. The judge looks after the justice end of it. The advocate looks after his client's interest and does the best he can for his client. Of course, it makes a poor judicial combination to have a bench made up of one judge and two advocates, if the advocates have just as much to say in regard to meting out justice as the judge does himself. That is a poor kind of arbitration board, and I confess that the criticism which has been pointed toward that board is a kind of criticism that meets with my approval.

I wish I could discuss the question more intelligently; and am sorry I did not read the paper before coming here this evening. I have been a good listener, however, and have learned something. I shall be glad to learn more by listening longer.

W. J. Crumpton, M. W. S. E.: This paper is not only a splendid presentation of the subject of arbitration, but it is highly suggestive of the broad views engineers must hold and live up to. The engineer who deals only with figures and inanimate materials so limits his field of usefulness that he cannot handle the more important questions which are confronting him today with ever increasing scope, and this is clearly brought out by a careful study of the paper.

An engineer, to take front rank in his profession and stand among the leading men of his community, must not only be capable of drawing correct deductions based on scientific principles and sound engineering, but he must go still further and be prepared to broadly consider living issues among men.

In dealing with the physical, engineers endeavor to reach the highest efficiencies in the structures for which they are responsible, yet the best over-all efficiencies can only be obtained by taking into consideration all conflicting human elements and arranging for their effective coöperation.

Arbitration stands for efficient settlement of disputes, and from that standpoint, at least, if for no other reason, it should be of vital interest to all of us.

George H. Bremner, M. W. S. E.: It has given me great pleasure this evening to listen to the discussion of this paper. I greatly appreciate the thoughts which Mr. Bates has presented, and the facts which he has brought to our attention. It would seem that engineers are peculiarly situated in regard to making decisions concerning public work. The necessity for an engineer to be an arbitrator, as our contracts all provide, probably arose originally from the fact that decisions on work that was in progress needed to be made immediately. There would not be time to refer the matter to others for adjustment, and the engineer was the logical one to make the decision as to what should be done, how the work should be carried on, and how the contract should be interpreted. Thus it naturally follows that the engineer becomes the final arbitrator between the contractor and his employer.

It would seem, in considering the question of arbitration, that we should distinguish between cases where it is necessary for the engineer to make immediate decision, which could not be referred to arbitration, and those decisions or settlements which do not require immediate action. This would be one class of decisions that would have to be excluded from arbitration, while the final settlement of a contract might well go to arbitration, or, as it frequently does, to the courts for final settlement.

Again, as the chairman said in his remarks early in the evening, arbitration means a compromise, and there is rarely a case brought before an arbitrator which does not mean give and take on both sides, and the umpire expects to give a compromise decision part

way between the claims of the two parties. It is not right that all cases should be decided in this way. There are many cases where it would be logically unfair to split the difference in any way between the two disputants. The courts, as a rule, are more inclined to be one-sided in their decisions than an arbitrator. They give the decision generally, though not always, in favor of one side to the exclusion of the other, which may be the fairest manner of deciding. And in cases where it is, settlement by arbitration may not be justified.

I presume the necessity for arbitration in engineering cases, or in cases between a contractor and his employer, is because our courts do not understand the technicalities which arise in such a dispute. The cases have to go to a jury for decision, and the ordinary jury does not understand the intricacies of engineering contracts and engineering work, and the lawyers sometimes only befog the jury instead of enlightening them, even when they understand the case themselves.

I present this, not with any idea of disagreeing with the author as to the necessity of arbitration, because I know from my experience with him and from cases which I have seen, that it brings about good results in many instances, but I merely suggest that not all disputes are capable of decision by an arbitration board.

C. B. Lewis, ASSOC. W. S. E.: I would like to say something, not in defense but in explanation of the so-called one-sided club clause in the contract. It refers more to the human than the construction side. There is little except praise to be given to the better class of contractors. They often do a great deal more than the most rigid interpretation of drawings and specifications requires. But the same cannot always be said of the foremen on the job; the drawings and specifications are always at hand, and are what the foremen look to for instructions. These foremen sometimes develop a surprising ability in technical interpretations, and if the drawings and specifications are constantly at hand, and they read those clauses that the engineer or inspector, or whoever he may be, is the sole interpreter of the specifications, it gives a great moral advantage to that man in some case which requires instant decision as to what should be done. There are some cases in which an immediate decision is the only feasible one. Take a case of reinforced concrete building construction, with girders running between columns and beams; the only time to do that work right is when it is first put in. We cannot cut out large beams and again get them satisfactorily framed in; the work must all be done at one time. Some question comes up as to how the concrete is to be mixed, whether the mixer is in satisfactory condition, or whether it is turned a sufficient number of times to obtain homogeneous concrete. One cannot stop work and let the concrete harden while he arbitrates as to what is to be done. The work must be done and must be

done right, and if the engineer takes up the work with that moral authority,—these club clauses,—he is a great deal more likely to accomplish what should be done.

James N. Hatch, M. W. S. E.: When a matter of dispute is left to arbitration, it often brings out a point that is of great importance in a quarrel, namely, that there is no real issue to quarrel over; and if the matter had been carried into the courts it probably would have cost a great deal of money and dragged out a long time; the disputants would never have discovered this important point. I have sometimes acted as an arbitrator, in a sense, although not in the real sense of an arbitrator, because the disputants who come before me seldom agree to stand by my decision; but they come before me and present their troubles, and I often find, when they have come together and have stated in the presence of each other just exactly what the troubles are, there is little further dispute. When each has heard the viewpoint of the other stated in a quiet way, it generally happens that they are perfectly willing to settle without further argument, and the matter is never carried any further. As I have said, the disputants seldom agree to stand by any decision beforehand, but I have noticed that the matter is seldom carried to any higher authority, and I am sure it has never gone into court, not in a single case. I think that in perhaps a large majority of the cases between contractors and clients the only real necessity is to get them together in a nice, quiet way, the arbitrator to sit in as an interested spectator and not let them quarrel, and they will settle the thing between themselves and be happy ever after.

Mr. Curtis: I think we should keep very clearly in mind that what we are talking about is a proposition to get a settlement of disputes by men who are qualified by their special knowledge to pass upon such disputes intelligently. It is surprising sometimes to see how courts will grasp technical matters, how quickly they will get hold of them; and it is also sometimes very surprising and discouraging to discover how slowly they get hold of them. It would hardly be thought of for a moment that a group of lawyers would submit matters of purely legal effect to men who are laymen, for determinations, which is exactly what we are called upon to do when taking a case to court. The courts may be entirely unfamiliar with that line of work. They may have no conception of it. Unfortunately, in the state courts, one cannot always pick his judge. This is a proposition to submit questions of a technical nature to the decision of technical men and men who will be able to value the evidence from a technical standpoint to determine where the truth lies and the bearing of that truth on the matter of damage. Doubtless none of us have any disposition to eliminate the lawyer. I know a good many of them and have business with a good many

of them, and in general I find them to be a fine class of men. Perhaps I am fortunate in not striking the shysters.

I have had the misfortune to be called into court on a suit a few times in the course of my life. I remember one case fifteen or eighteen years ago where I represented the contractor. The subcontractor was dissatisfied with the allowance which the engineer had made him. I offered the man more than the engineer, because I thought the engineer had been a little too technical about the matter, and I was willing to give the contractor more than the engineer had been willing to give him. He was still dissatisfied and took the matter into court. I remember sitting there day after day and looking at that jury while this accounting was being made and wondering how much of it was really getting into their heads. Well, I had no cause to find fault with the decision of the jury; as a matter of fact, I think the gentleman got about what I offered him and no more. But that is not the point. The point is that these things should be possible of solution and determination by men who know, men who can properly value evidence, not by twelve men picked up from the streets who know absolutely nothing about the proposition.

Recently I had a case in which I was compelled to go into court as a complainant on a contract, and in my wisdom I left it to the court to determine. I am sorry to say the court did not measure up to his opportunities, so that the case is now pending in the Appellate Court. We hope three judges will know more than one. That was a case where we had a perfectly honest and, from his standpoint, a perfectly capable judge; but he failed to grasp the situation. If it had been submitted to arbitration with three arbitrators chosen for their ability to pass upon such questions, I think they would have found a different conclusion. Let me say I think that judge would have found a different conclusion if he had had the evidence written up at the time he rendered his decision, so that he could have read it over and got it set in its proper position. Unfortunately he did not have it.

I want to speak again of this radically wrong method of selecting arbitrators, which has been the general custom, wherein one man picks one arbitrator and the other party to the dispute picks another and the two agree upon the third. If a man came to me under such circumstances and wanted me to act as an arbitrator I should insist upon getting the two disputants together and I would say, "Now, gentlemen, I want to understand first what your idea is as to my position in this matter. Am I an advocate or am I an arbitrator? If it is understood that I, representing the complainant, and my friend here, representing the defendant, are simply counsel and that we represent the gentlemen who have selected us, well and good. I am perfectly willing to act under those conditions, but I want it understood. I am either a judge or a counsel, one or the other. I cannot be both."

I hope when Mr. Bates comes to write the final closure for his paper that he will go a little further on one point than he has so far gone, and that is to indicate more definitely the method by which he proposes the arbitrators should be selected. Simply as a suggestion, I am going to offer an idea of my own, and that is that each disputant be required to submit the names of a specified number of men who would be satisfactory to him as an arbitrator, and that list should be large—at least ten. Then make it the business of the other disputant to select from that list an arbitrator. Until I hear some better way of getting men who will represent both sides, men who will be judges and not simply counsel, that seems to me the most favorable method. I have not lost sight of the fact that Mr. Bates has suggested that if we cannot do any better, the disputants should each select some one who should select for them an arbitrator; but still that to me is not quite satisfactory. That is a question which I think it is very necessary should be worked out in order to put this where we want to put it, namely, in such tangible form that it shall be here ready for any one who cares to make use of this principle of arbitration.

Charles L. Strobel, M. W. S. E.: Mr. Bates' valuable paper is a strong plea in favor of settling our differences by arbitration. It should be carefully read and studied by the members of this Society and others, and I hope its recommendations will be heeded.

Our administration of the law is indeed most unsatisfactory, and it is a matter of the highest importance that it should be radically changed. President Taft has taken the lead in calling attention to the defects of our criminal procedure, and it is refreshing to see signs that the legal profession, which is so strongly represented in our political life, is at last taking up the cause of this important reform. Mr. Stein's statement that "a trial in court is regarded and treated as a battle in which the combatants may without loss of self-respect use all means not bordering on the downright criminal to gain their ends," is, we all know, fully borne out by the facts. We do not always realize the bad effects such practices have upon the people in general, as well as upon the practitioners of the law. As regards the latter, Mr. Stein mentions that it rarely occurs to them "that there is anything immoral in pleading two inconsistent defenses, each of which gives the lie to the other." So long as our legal methods permit, if they do not encourage trickery, justice often is not done and there can be very little respect for the law. We have a Sherman Act on our statute books, which, it seems now clear, cannot be enforced, but which many people consider justified by the use that can be made of it as a club to hold over certain of our big corporations, regardless of the fact that it is a menace to any number of other business firms and individuals. I do not believe that there can be such justification, and I think it morally wrong to have a law on our statute books which

cannot be enforced. There must be something wrong with the law. So we have taxation laws which are not enforced because they cannot be; it is wrong to have them, and their influence is corrupting.

In our specifications and contracts for engineering work it has become more or less customary to lean to an extreme in giving great and arbitrary power to the engineer in charge, who, after all, is the employe of his client, the owner. It is not right to do so and has a tendency to create a spirit of unfairness. Engineers should do their share towards bringing about better conditions in this respect. Let us have fair play in all things, in the letter and in the spirit.

A more frequent resort to arbitration for the settlement of disputes should develop a class of engineers who have the experience and training requisite to enable them to act satisfactorily as arbitrators, and such work well performed can only greatly improve the standing of engineers in the eyes of the business world. As both sides to a controversy must want to obtain a fair settlement if arbitration is resorted to,—otherwise it will not work,—it is clear that the more frequent use of this method of the settlement of differences must tend towards establishing a greater spirit of fairness generally, and that is a boon much to be desired.

J. W. Alvord, M. W. S. E.: I have read with much interest Mr. Bates' valuable paper on Arbitration, and feel that he has done a great deal to make clear some of the underlying principles which should govern the arbitrator in the important and difficult task to which he is called.

It is a theory of mine that arbitrators are born and not made, at least to the extent of the human temperament required this must certainly be true, and while an arbitrator may need special knowledge along the line on which he is asked to pass judgment, the important fact yet remains that in many ways he is called upon to exercise patience, courtesy, thoroughness, and breadth of view, which are not found in every one, however well meaning and conscientious he may be.

I am particularly pleased with the stand which Mr. Bates takes against the common practice of having the members of an arbitration board chosen, one to represent one side, and one the other side; they two to choose a third. This method in my opinion is a thoroughly vicious way of selecting an arbitration board. I have put myself on record against it a number of times before the American Water Works Association and in other public ways. It has been my fortune to serve on a good many arbitration boards selected in this manner. My observation has been that even the best and most well intentioned men selected under such conditions will gradually, imperceptibly, and unconsciously drift apart, so that

the man selected by both parties is really sole arbitrator, hearing arguments from opposing points of view. Exceptionally good men and high-minded men, with natural patience and lack of bias, may overcome this handicap, but the greater the responsibilities devolving upon them the greater the temptation and strain becomes. Some time since I had occasion to formulate an ordinance for a coöperative water works franchise, in which this question came up and was fully discussed by attorneys representing each party, and the final decision in the matter was embodied in the following clause:

> "The value of such property and water works system shall be ascertained and fixed as of the date of ...., by three disinterested hydraulic engineers, to be selected and appointed by the City and by the Company, by mutual agreement, *and no one of whom shall be considered or shall be the representative of the interests either of said City or said Company.*"

Every board upon which I have been appointed that has been formed in this manner has been a harmonious and successful board, seeking only just and most impartial results, and working with much greater efficiency, due to lack of conflicting or unfair influences.

The work of an arbitrator requires great patience and courtesy. Such work requires that a man should be healthy and happy, and have breadth of view, which will carry him through all sorts of petty snarls and difficult situations. Few men enjoy the work of arbitration unless they possess all these qualities. A man should have the ability to give and take, to compromise where compromise is possible, and he should be willing to accept decisions against him with fortitude, even though he may consider them as more or less fatally defective.

In spite of all of these drawbacks, as Mr. Bates has well said, the work of an arbitrator is of the highest possible service to mankind, and he should welcome the opportunity to render a fearless and impartial decision which he believes to be right in spite of all adverse influences and conflicting suggestions which come to him, which tend to obscure his vision or warp his views.

CLOSURE.

The Author: I have read with great satisfaction the discussion of my paper on Arbitration. Its primary purpose was to excite the interest of my brethern and to elicit their opinions on the subject. The paper was incomplete without this discussion and its value is enhanced by the contributions of engineers so competent from experience to advise regarding the settlement of disputes, which occur in the practice of our profession.

In closing the discussion I wish to say that I deprecate any

idea of making it easier to quarrel by suggesting improved means of adjusting quarrels. Arbitration is only recommended for occasions when the parties are really unable to agree between themselves and when they really desire to reach an equitable settlement. Neither am I to be understood as advocating in any degree the depreciation of the engineer's authority. An engineer, applying for membership in this Society, must qualify for the honor by a statement of his experience in "responsible charge of work."

Authority and responsibility are inseparable—one cannot exist without the other. Therefore the engineer's authority during the progress of the work is practically absolute. Work under his charge cannot be suspended or delayed because the contractor differs with him as to the manner of its execution, the terms of payment, or upon other accounts. The engineer must be the interpreter of the contract while the work is proceeding, and if in this exercise of his official prerogative the contractor unjustly suffers, the latter is entitled to relief through arbitration or other means of securing justice. The question as to whether engineers are good and contractors are bad, or vice versa, has no place in this discussion. Both parties have their rights in equity and as far as is possible the rights of both parties should be conserved in the contract for the work. It is held in the paper under discussion that the provisions for the settlement of disputes usually introduced into contracts are inadequate to secure justice, and that they should be replaced by other provisions which are fair, clear and practicable. From the very nature of engineering work where its extent is not visible in advance, the specifications are based on conditions which, in some part at least, are assumed to exist, and during the progress of the work new conditions are developed different from those anticipated at the time the contract was executed. It is to be expected that if these new conditions increase the cost of the work in certain particulars, there will be other particulars in which there is a reduction of cost. With all the knowledge obtainable by the engineer and contractor, it is impossible for either of them to estimate in advance the exact cost of the work; and this is so well understood that it is customary for each of them to include in their estimates an allowance for "contingencies." This allowance being sanctioned by reason and custom, it is fair that the contractor should stand the increased costs and should benefit by the reduced costs, within reasonable limits. In the matter of costs the interests of the parties are directly opposed,—one desiring to pay as little as possible for the work and the other party equally desirous of getting as much as possible for it. On account of the nature of contract work and the attending circumstances, it is almost inevitable that the representatives of the parties in their proper zeal for the interests of their respective employers will fall into disputes on questions of quality, quantity, times, methods, and others which engineers are accustomed to meet. These disputes must be settled

by the engineer, but his decisions should not be "final and binding" on the contractor. The contractor should not be deprived, by contract or otherwise, of his natural right for relief when he suffers from an unjust decision of the engineer. It would be unreasonable and inexcusable for the work to be stopped each time the employes of the parties differ in opinion about it. This is well illustrated in the remarks of Mr. Lewis in which he shows that engineers must be prepared to make "instant decisions," and gives examples where such decisions are necessary. The engineer must be in complete charge of the work during its progress, with responsibility for settling all questions requiring immediate action and with authority to defer such as may be held in abeyance. This is clearly shown in Mr. Bremner's discussion. The point I wish to emphasize is that the engineer's decision ought not to be considered as final and binding, and this point is not disputed by those who have taken part in the discussion. If at the completion of the work, or at any other proper time, it is necessary for a settlement under the contract that the intervention of a third party shall be secured, then arbitration is much to be preferred to an appeal to the courts, for the reasons which follow:

Construction problems involve assumed and indeterminate factors, and are to be solved by the exercise of reason and judgment, and not by technicalities of the law. The arbitrators are not bound to observe trifles and they are the judges of what is material and relevant. They are to use reason and judgment and to make a just and true award according to the best of their understanding. If, as sometimes happens, the contractor in anticipation of obtaining additional compensation when the work is completed, makes a record covering all sorts of claims, some of which ought not to be made and which should be covered by his estimate for contingencies, other claims the proof of which has been destroyed by the progress of the work, and still others which it will be difficult for the engineer to disprove; then the arbitrators may weigh and value these claims and may balance them against counterclaims and, after a full hearing, may render such award as they deem just and equitable. There is also the special advantage that the parties in dispute choose their own judges and may by the terms of the "submission" which they adopt, confine the arbitration within limits which are mutually agreed upon. The engineers prepare the contract forms and with authority to make decisions, have no cause for appeal. If they are willing to grant the contractor the right of appeal, they certainly have the ability to provide a form of contract under which equitable settlements can be made to the advantage of all parties.

The very fact that a contract form provides for arbitration opens the way for the settlement of disputes without reference to a third party. There is much wisdom in the remarks of Mr. Hatch and I agree with him "that in perhaps a large majority of the cases between contractors and clients, the only real necessity is to get

them together in a nice quiet way * * * and they will settle the thing between themselves." If the contract provides for arbitration, they must come together before they can arbitrate, and meeting on equal terms the opportunity is favorable for a settlement without arbitration.

Mr. Symons has asked what will be "the effect on the profession of law, by a more general resort to arbitration in adjusting disputes?" I think if there is any visible effect it will be for good. Alderman Pringle, in discussing arbitration from the standpoint of a lawyer, says, "he (the lawyer) ought to be a man who goes into court as a last resort. If he is loyal and faithful to his clients, he ought to advise them in such a way as to keep them out of court; and, if possible, to secure justice without going into court." From this it may be taken that a lawyer should favor and promote mediation and possibly arbitration. There are many cases where lawyers should be chosen as arbitrators and there is room for them in a board of technical experts. If arbitration opposes, or in any manner conflicts with the law, it is worse than useless—it is vicious. But it neither opposes nor conflicts with the law. It must work under the law and it is advocated as a means of obtaining lawful settlements of disputes with certain advantages to the disputants which are hereinbefore mentioned and need not be repeated. We cannot get on without lawyers, even in arbitration cases, and it may have a salutary effect on the legal profession for its members to drop for a time the role of advocate, and to consider controversies with the purpose of securing just and equitable settlements.

Mr. Trumbull asks about "the legal effect that may be given to a decision of a board of arbitration, and as to whether one of the individuals, making a submission to such a board, can withdraw before the award is made?" Also, if "there should be an enforcement of the award by statute?" These questions show the necessity for consulting lawyers. My opinion is that the award should have full legal effect, that a party shall not have "the right to withdraw or revoke the submission after the arbitrator or arbitrators have accepted their appointment, except by mutual agreement of the parties who subscribed to the submission," that it is better to have the award entered as a judgment and decree in a court of record, and finally, that these points ought all to be covered in the submission which should be drawn by a lawyer or by some one possessing the requisite legal knowledge.

Mr. Trumbull also asks "if I hold that a Government contractor has no relief against unjust decisions on the part of the engineer in charge of the work?" In reply to this question I am not able to say that a Government contractor has "no relief," but I may express my belief that his chances for relief are slight in comparison with those he enjoys under contracts made with private individuals or corporations. In so far as I know, the Government contractor's only source of relief is the United States Court of

Appeals, and I have been led to believe that a suit in this court means years of time coupled with heavy expense. My experience as a Government contractor is limited to one contract, and in this case I felt I was entitled to claims which were denied by the Government engineers. I thought of appealing to the Court of Claims, and after getting legal advice formed the opinion that I might ultimately win at least a portion of my contention. But when I reflected that I could only hope to enjoy a few more years of active work, I concluded that my time would be more agreeably occupied and my labor better repaid by serving private clients, than would be the case if I spent my last years in fighting the Government. In this instance I and my associates plead with the Government officials to have our differences submitted to arbitration. These officials would not consent to arbitration, neither would they agree to appoint disinterested engineers to examine and report on our claims for their further consideration, although we offered to bear the cost of the report. There are cases where contractors were not content to surrender their claims and were successful in getting relief through the Court of Claims. If two such cases are inserted herein, it is to show on the testimony of the court itself that Government contractors may have grievances which the Government must recognize, and that means of relief are not entirely denied to these contractors. These court decisions will carry greater weight to the minds of my readers than individual experiences and opinions, which the reader may think originated in the natural disappointment of a contractor who believes the Government owes him money which he cannot collect. The decisions above referred to and which follow are abstracted from the *Engineering Record* of March 30th, 1912:

"THE DISCRETION OF GOVERNMENT ENGINEERS.

By William B. King,

of the Bar of the United States Court of Claims.

"The recent decision of the Court of Claims in the case of Axman v. United States, and the Savage Construction Co. v. United States, are of more than ordinary interest to contractors in showing the willingness of the courts to place some limit upon the discretion of the engineer officers engaged in superintendence of complicated contracts.

"In the Axman case the contract was for the removal of three rocks known as Shag Rock No. 1, Shag Rock No. 2, and Arch Rock, in San Francisco Harbor.

* * * * * * * * * * *

"The Court of Claims made the following finding in relation to the officer in charge:

" 'The engineer officer in charge of the work manifested toward the claimant from its beginning to its close a feeling of intense dislike and prejudice, and at times treated him with extreme discourtesy and unreasonableness. He admitted disappointment in claimant securing the contract over a personal friend of his, and repeatedly and persistently claimed claimant's inability to perform the work because of inexperience and inadequate compensation prior to his commencing work thereon. A short time subsequent to the execution and before any work had been commenced, he endeavored to have the contract annulled for failure to furnish the bond provided therein as promptly as he thought it should have been done, and he made a similar attempt subsequent to the explosion of Arch Rock by the claimant. His construction of the contract and specifications was uniformly technical in the extreme; he declined to grant reasonable and courteous interviews, and dismissed polite appeals with harsh and profane language. His exactions under the contract and his rulings in respect thereto were so erroneous and unjust as to imply bad faith.

" 'The contractor elected to commence work on No. 1, but by so doing it cannot be reasonably asserted he precluded himself from joint operations if the organization of his force and his interests, as well as the interests of the defendants, would be advanced thereby. His plans for the removal of both Shag Rocks had been submitted to and approved by the engineer, and if the circumstances of the case and the situation of the parties at the time characterizes the rulings of the engineer as an arbitrary and unreasonable exercise of his discretionary power under the contract the consequential loss is recoverable.'

"Judgment upon the whole case was awarded to the claimant for $68,720.23.

"In the case of the Savage Construction Company, the contract was for the construction of foundations for abutments and piers for four aqueducts along the Illinois and Mississippi canal.

* * * * * * * * * *

"The contractor claimed the retained percentage, the loss on the sale of material on the ground and his expected profits. The government interposed a counter claim and asked for the difference between the claimant's contract price and the cost to the government to complete the work after the annulment. The court gave judgment for the retained percentage and for the loss on the material, but found that there would have been no profit on the completion of the entire contract and dismissed the government's counter claim, basing these conclusions upon the following finding:

" 'Upon the foregoing findings of fact the court finds the ultimate facts, so far as they are questions of fact, that the annulment of the contract at the time and under the circumstances set forth herein was so capricious and erroneous as to imply bad faith on the part of the engineer officer in charge and, therefore, in violation of the claimant's rights under the contract, to its damages, as found.'

"The court's opinion said:

" 'The claimant's contention is that the annulment under the conditions stated was capricious and in violation of the contract and therefore without warrant in law. With this contention we agree.

" 'By the terms of the contract the authority to annul the same depends, so far as material here, upon whether the contractor "in the judgment of the engineer officer in charge" failed 'to prosecute faithfully and diligently the work' in accordance therewith.

" 'The failure to complete the work within the original contract period, we have found, was in effect the fault of the contractor, but the contract having been extended, said failure, though the same might have been considered by the officer in determining whether a further extension of time should be granted (*United States* v. *Gleason,* 175 U. S., 588, 606), could not be considered as a basis for the annulment of the contract, as all prior delinquencies in that respect were cancelled when the contract was extended. True, as held in a long line of decisions both by the Supreme Court and this court, the decision of the engineer officer in charge, in the absence of fraud or such gross error as to imply bad faith, will control in matters wherein he is required to exercise his judgment. (Kihlbery v. United States, 97 U. S., 398; Sweeny v. United States, 109 U. S., 618.)'

"It has been a constant subject of complaint by contractors that under the forms of contract in use upon government engineering work of all classes, they are left entirely to the mercy of the particular officer who may be in charge of the work. While this is true to a very large degree, yet these decisions show that the courts will go no further in enforcing one-sided provisions of the contract than they are required to do by their terms, and that relief will be given to the contractor wherever it appears that the engineer has acted unreasonably, capriciously and without discretion."

It would be difficult to find a better argument than is contained in these court decisions, in favor of arbitration provisions in Government contracts. Theoretically, the Government intends to deal fairly with its citizens; practically, it enters into contracts with its citizens on terms which would not be regarded as fair, or even

lawful, in contracts where both parties are citizens. The principle of a Government by the people and for the people does not appear to apply to contracts between the Government and the people. I trust I shall not be considered disloyal to my Government when I say it is possible for the highest office in the Government to be filled by a man whose chief characteristic is arrogance, and who may set the fashion of smiting his fellow citizens (except at such times as their votes are wanted), and that this fashion may be passed down the line until the "big stick" lands on the back of the Government contractor. That the Government is not bound by the laws under which it prosecutes its citizens is shown by the following, taken from the *Railway Age* of April 28th, 1905:

> "GOVERNMENT MAY ACCEPT REBATES.—The Attorney General of the United States has decided that the provision of the Interstate Commerce Law, stating 'That nothing in this act shall apply to the carriage, storage or handling of property free or at reduced rates in the United States,' is to be construed as meaning that the Government may relieve itself of the cost of transportation charges by accepting the so-called rebates for the transportation of material for contractors engaged on the reclamation work of the Government or any other concessions in rates which the roads may be induced to give where the Government is not in competition with private manufacturers."

To complete the illustration an extract is taken from the Sixth Report of the United States Reclamation Service (1906-1907), which reads as follows:

> "The total expenditures for freight during the last fiscal year were $278,782.10. The commercial charges on the shipments covered by the above expenditures would have been $470,863.26, showing a saving of $192,081.16. The deductions on account of freight contracts with the railroads amounted to $173,713.15. In addition, the transportation office has received from the railroads $18,106.68 on account of land-grant deductions and $261.33 on account of loss and damage."

Further comment on Government methods of carrying on its civil works is unnecessary.

With the work now being done under the direction of Government engineers, and its apparently increasing volume, it is suggested that clauses in their construction contracts providing for disinterested arbitration, are even more necessary than in contracts where all parties are citizens. If such a reform were instituted, the Government would be able to let some works by contract which are now executed by day labor, and thus reduce the number of Government employes, and this would be in accord with our

democratic principles. When the Government is considering arbitration treaties for the settlement of all disputes with foreign nations, it surely cannot be out of place for it to confer the benefits of arbitration upon its citizens in the cases where the Government is a party to a contract with them.

The purpose of this paper was to present to engineers, and through them to men of other occupations, arbitration as a means of settling justiciable differences, and we must not lose sight of its general application by confining our discussion to its particular application in the settlement of contractor's claims. Engineers, like other men, have all sorts of disputes with all sorts of people. For instance, we are, in one way or another, interested in what is commonly called the labor troubles. Some people claim that the labor problem is the greatest which confronts our nation. Be that as it may; we do know that we are never free in this country from labor disputes. We have disputes about wages, disputes about jurisdiction, and frequently disputes about nothing at all, and the country is never free from labor disputes which are injurious to employer and employee and which entail great economic loss that is ultimately distributed among our citizens. The curious thing connected with this situation is that the law does not appear to provide a remedy for it, and that those who make and execute the laws shun the labor problem as it were a plague. This is perhaps one of the fruits of universal suffrage. The result of these conditions is that arbitration is appealed to as the last bar which precedes anarchy. Such strong language should be supported by evidence. Let me give you some illustrations from the railway situation, with which so many engineers are identified.

Charles Azro Prouty, Chairman of the Interstate Commerce Commission, has been a member of that body since 1896, and no one has had better facilities for studying railway matters. On March 28th, 1912, at the dinner of the Traffic Club of Pittsburgh, he is reported to have said:

> "I believe in organized labor. Capital is of necessity organized, and labor must also organize if it would cope successfully with capital. But combinations of labor, like combinations of capital, are in the nature of monopoly and may be tyrannical and oppressive. No form of labor is more highly organized than railway labor in certain classes, and the very fact of this more perfect organization has enabled that labor to secure, in comparison with other forms of labor, excellent compensation. I do not intimate that railway wages are too high, for I have no thought of that sort. Suppose organized railway labor makes a further demand for increased wages, and that the railways accede to this demand. The increased wage adds to the expense of operation and reduces net revenue. The railway applies to the Interstate Commerce Com-

mission for leave to advance its rates on this account. What, now, is to be the answer of the commission?

"The railway rate is paid by the whole body of the public. If, therefore, this increase in wages was unjustifiable, and if on that account an increase in rate is allowed, it results that the general public, including all other forms of labor, is required to pay what is unjust and unreasonable. Must not, therefore, the Government be satisfied, not only that the added wages are paid by the railways, but that they are necessarily and properly paid? And is not the railway thus placed in a most unfortunate and embarrassing dilemma?

"Consider this matter for a moment now from the public viewpoint. It was recently suggested that certain demands would be made by railway labor in a certain section of this country which would be supported, if not complied with, by a general strike of all classes of trainmen. Such a strike would be altogether possible today. Think for a single moment of the consequences; suffering, riot, death must result. Ought not the public to protect itself against the consequences of such possible action?

"We have the Erdman act, and this has given most admirable results, but that is a peace-measure, obligatory upon no one, and of no value in time of war. I have believed that it would finally be found necessary to provide by federal enactment that no strike shall be declared by organized labor upon any interstate railway until the question at issue has been submitted to arbitration, and a certain length of time has intervened after the award, and after notice that the strike would be inaugurated notwithstanding the award. It is doubtful if we could compel either the railways or the employees to comply with the award, but, certainly, in view of the stake which the public has, the Government may require of the railway, as its servant upon the one hand, and of organized labor, as a condition of its organization upon the other, that the use of these public facilities shall not be interrupted until every attempt has been made to avoid that necessity.

"Probably neither party would approve such legislation. The railway manager would say that every arbitration means a compromise; that he must, as a matter of fact, although nominally a free agent, comply with the award, which is probably true, and that, therefore, you take out of his hands the management of his property.

"The employee would object because he is thereby to an extent deprived of a weapon of offense in the enforcement of his claim, and since it would be difficult for organized labor to enforce a strike against public opinion in case of an adverse decision.

"But is it not after all for the interest of all parties that these questions should be settled by peaceful methods rather than by the waste, the misery, the possible bloodshed of a great strike, and is it not better for both parties that the Government should have sanctioned the increase, if one be made, and must, therefore, of necessity sanction the increased rate with which to meet it, if need be?

"I have made this suggestion, however, not for the purpose of suggesting a remedy, but simply because the thought has been presented to me as one charged with the regulation of railway rates. It has been to me a difficult question to determine exactly what my duty might be in a case of that sort, and it will come to my successor in precisely the same form. He should, if possible, be relieved from that embarrassment."

Such a strike as Chairman Prouty referred to in his speech, has recently been averted for the present by reference to arbitration. The following reference to this case is abstracted from an editorial in the *Railway Age Gazette* of May 3rd, 1912:

"THE EASTERN ENGINEMEN'S WAGE CONTROVERSY.

"The eastern roads and their enginemen having agreed to arbitrate their differences, the only step preliminary to arbitration that remains to be taken is the selection of the personnel of the board. A review of certain developments in this controversy is now timely. The eastern railways not long ago sought leave from the Interstate Commerce Commission to advance their freight rates. Their chief argument was that their operating expenses had increased and still were increasing, mainly owing to increases made and being made in wages. The commission replied in part that before it could permit rates to be advanced on account of increases in operating expenses, including wages, the roads must establish to its satisfaction that these increases in operating expenses, including wages, were reasonable. Naturally, when the question of another raise in wages was presented to the eastern railway managements, they desired to have the question of its reasonableness determined by the same body which had said that it would determine the reasonableness of changes in their rates largely according to its findings as to the reasonableness of their wages.

"But the law does not deal with the wages of interstate railway employees as it does with the rates of interstate railways, out of which those same wages must be paid. It creates a commission and says the roads must submit their rates to arbitration by this commission. It does not designate arbitra-

tors to whom employees must submit questions of wages; it does not require them to submit these questions to arbitration at all. And when the eastern railways proposed that the engineers' wage question be arbitrated by the same body that determined the rates railways may charge, the engineers declined the proposition. This could mean only one of two things, viz., that either (1) the employees did not consider the body the government had created to wisely and impartially determine what rates the railways might charge as wise enough and impartial enough to determine fairly what wages the employees ought to receive, or, (2) the employees did not want to submit their case to a body that was wise enough and impartial enough to determine fairly the wages they ought to be paid. On the former theory, the employees did not think the commission would give them a square deal; and on the latter theory they did not want a square deal.

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"The action of the commission in declining to serve in a voluntary arbitration proceeding, when one of the parties had indicated its services would not be acceptable, cannot be criticised. The whole situation demonstrates more clearly than any other that ever has developed the need for the adoption of some scheme of arbitration which will be, in effect, if not in a technical legal sense, compulsory, and which will lead to fair, thorough-going and scientific investigations and determinations of wage controversies between railways and their employees. An agreement has now been reached to submit the controversy to arbitration by a board composed of one representative of the enginemen, one representative of the railways and five other persons to be chosen by these two or by the chief justice of the United States Supreme Court, the chief justice of the Commerce Court, and the labor commissioner of the United States, acting together. The railways' indisposition to submit the matter to a board organized under the Erdman act and composed of one representative chosen by the employees, one by the roads and one by these two or by the ex-officio mediators under the Erdman act, Messrs. Knapp and Neill, is not surprising. The railways have had experience with arbitrations under the Erdman act, and know they almost invariably result in compromises involving advances in wages and based on no principle whatever. A settlement of the question by such a board as that provided for in the agreement between the railways and the enginemen will be much preferable to a makeshift arbitration under the Erdman act. But there will be other similar controversies, and there ought to be some means for settling them all according to fair and consistent principles. That they may be settled according to

consistent principles, there is need for a permanent board of arbitration. That they may be settled justly, there is need that this board shall be created by and represent the public through the national government, and that its findings shall be binding on the Interstate Commerce Commission in rate cases. The workmen's compensation bill prepared by the federal commission on Employers' Liability and Workmen's Compensation, which is now before Congress, provides that payments made by the railways under its requirements shall be accepted by the Interstate Commerce Commission in determining the reasonableness of rates, as reasonable operating expenses. Wage settlements should likewise be made by a federal court of arbitration whose findings should be similarly binding on the Interstate Commerce Commission."

The newspapers of May 17th, 1912, report Mr. B. L. Winchell, President of the Frisco Lines, as having said in an address to the Transportation Club at Peoria, Illinois:

> "We will some day find a practical way, also, to have compulsory arbitration. It will some day be a legal crime for a railway employee to strike as well as for a railway official to refuse to arbitrate."

In illustration of the state of mind towards arbitration, in another class of workers, attention is called to an editorial in the *Chicago Daily News* of April 15th, 1912, which reads:

"THE SHORT ROUTE TO JUSTICE.

"Action taken last week by one of Chicago's large commercial institutions ought to have the effect of stimulating good feeling between the workers and their employers. It at least will have a tendency to prevent strikes, lockouts and similar industrial disturbances which in the past have proved costly and irritating not only to the immediate parties in interest, but to that greater third party, the general public.

"The reference is to the agreement reached between the firm of Hart, Schaffner & Marx and its employees. This agreement is the outgrowth of the plan of arbitration of disputes and differences between the firm and its workers that has been in operation since the settlement of the garment workers' strike more than a year ago. It is, in fact, an extension and enlargement of the arrangement whereby disagreements were taken before two arbitrators, one representing the dissatisfied workers and one the firm.

"Now it is agreed that a trade board shall be organized. Five of its eleven members will represent the workers, five will represent the firm and the eleventh—the chairman, who

will vote only in case of a tie—is to be chosen by the ten others. No question that arises, however, is to be submitted to the board until its merits have been considered by a deputy for the workers and a deputy for the firm. The trade board is to be reached only through an appeal from the decision of the two deputies or in case they disagree.

"Such appeals, it is expected, will be rare. That, at least, has been the experience in the cloak and suit industry in New York City, where a similar plan has been in operation during the last eighteen months, involving 200 manufacturers and 50,000 operatives. Grievances are heard each week as a matter of routine, but they are promptly settled, and only in a few instances has it been found necessary to resort to the arbitration board. The persons concerned in adjusting the differences are fully informed as to the conditions of work, the technicalities of manufacture and all phases that bear upon the subject, so that adjustment is more readily and satisfactorily effected than when arbitrators not so informed are called upon.

"It is reasonable to suppose that an arrangement of this character, providing for quick settlements of honest differences, will tend toward a much larger measure of fairness and justice than can be reached through tedious, costly strikes and similar upheavals which beget bitterness and suffering."

There is so much discontent with conditions throughout the country, such dissatisfaction with the laws and with the practice in the courts, that our people are looking for objects on which to vent their displeasure, and for new remedies for their real and fancied grievances. Heretofore, the cry has been for more law. Every time a man does not like anything he proclaims that there ought to be a law against it, and the politicians among our lawmakers have catered to these desires. It is charged against a legislator that he tried to have a law passed making the circumference of a circle three times its diameter, so that the "plain people" could figure it. This sort of thing has brought the law into unmerited contempt and people are looking for something to take its place. Some of them think everything is to be accomplished at the polls, that the voice of the people is supreme wisdom, and no problem is too hard to be solved by a majority of votes. A remedy of this kind will soon break down of its own weight and our troubles will still be with us. Our minds are in that state in which arbitration is welcome and it is becoming popular to propose it as a substitute for those things we do not like. Now is the time to test its value and it will be a pity to make a fetich of it as in the case of some recent fads.

The strange thing about arbitration is that while it appears to be so acceptable we have not learned how to use it. This discussion of arbitration will be of great benefit to our members if it leads us to learn the right use of it.

Our members who have taken part in this discussion seem to be agreed that the weak point in arbitration is the difficulty of getting the right men for arbitrators. Mr. Alvord has a theory "that arbitrators are born and not made." His theory is doubtless right, in part, but the same may be said of a judge, and litigants may choose their arbitrators, which is to their advantage when compared with their involuntary appearance before a judge who owes his place to a popular election or to a political appointment. There is a wide range of choice in the selection of arbitrators, and I know of no class of men more suitable by education and practice for service as arbitrators than engineers. Mr. Strobel speaks of the advantage to engineers through the experience and training which they will get by serving as arbitrators. It cannot but have a good effect to look at both sides of questions and to practice judgment in finding where the merit lies.

Mr. Curtis asks me "to indicate more definitely the method by which I propose arbitrators should be selected." He also offers a method of his own "that each disputant be required to submit the names of a specified number of men who would be satisfactory to him as an arbitrator, and that list should be large, at least ten. Then make it the business of the other disputant to select from that list an arbitrator." His plan has much to commend it. I had experience of a somewhat similar nature. Two parties in dispute each selected an arbitrator. I was the choice of one of the parties and we two arbitrators, thus chosen, were to select a third arbitrator. Each of us rejected the other's nomination for third arbitrator, and it looked as if we could not agree on a third man. At this juncture, I made a list of fifteen members of this Society which I presented to the other arbitrator with the statement that he must accept one of the fifteen, and if he failed to do so I would retire from the case. He chose one of the number, who accepted the office, and the arbitration concluded with an award which was accepted by both parties. When I recall this case it only confirms my opinion that arbitrators should never be chosen, one by each party and the two so chosen to select a third. Mr. Curtis' method is much to be preferred. I have no particular method to recommend but I think it ought to be a fixed principle that each arbitrator should be the choice of all the parties, and that an arbitrator should stand in exactly the same relation toward each of the disputants. As to how such impartial arbitrators can be obtained I can only say it is up to the disputants to find and engage them. We constantly

have to find and choose in many different lines. There are probably ten million marriageable women in this country among whom we choose our wives. In just the same way we may choose any other arbitrator. If I may be pardoned for giving my own case as an example, I can say with some pride, that at present I am engaged as an arbitrator and that at the time of my appointment as such I had no acquaintance with the parties in dispute, nor any knowledge of the subject of their controversy, and that the fixed principle advocated above is maintained in this case. The parties wanted an arbitrator in accordance with that principle and looking for one, the choice happened to fall on me. If it should develop that they were mistaken in their choice, they will have the consolation of knowing that they acted on the right principle.

I will end this discussion, as I did the original paper, with the recommendation that engineers establish a code for arbitration.

WATERPROOFING OF ENGINEERING STRUCTURES

W. H. Finley, M. W. S. E.

Presented March 18, 1912.

My attention was first directed to the necessity for some method of waterproofing engineering structures by the number of limestone masonry arches that were slowly but surely deteriorating, due to the infiltration of water. Investigation disclosed that very little had been attempted along this line, and no definite information regarding methods or materials could be obtained. The waterproofing of a masonry arch presents no very difficult features, and my earlier attempts in this direction met with a fair degree of success. However, since the extensive elimination of grade crossings in cities by the elevation of railways began, the problem of waterproofing has been greatly complicated by the necessity for making the subway bridges water-tight.

This has caused a rapid development in both methods and materials for waterproofing, until now there is all sorts of information as to how it should be done and what materials to employ; yet the problem is a long way from being satisfactorily solved. Engineers have received some rude shocks in this line of work, causing them, at times, to doubt whether it was possible to do a satisfactory job of waterproofing. The rapid expansion in this field has brought into existence the waterproofing "expert," who takes his place along with the paint expert who has for years periodically offered us a paint that would at last prevent the corrosion of metal structures, and yet the corrosion of metal structures still goes on.

An engineer, confronted with the problem of constructing a water-tight bridge over some street or avenue, is approached by a waterproofing expert who, with seductive eloquence, extols his methods and materials until the engineer's doubt vanishes and he adopts the scheme. When the work is finished he looks at it with glowing pride and, like Archimedes of old, exclaims "Eureka." Six months later, however, when the serenity of his existence is rudely disturbed by an inspector exclaiming "that bridge over 'steenth street leaks like a sieve" (why do they always say "leaks like a sieve"?), the engineer's former Greek exclamation is apt to be replaced by an Anglo-Saxon expletive that is not permitted in polite society. Do not blame the engineer for being so unsophisticated. I have listened to a waterproofing expert explain the superiority of his material with an earnestness that was most convincing, and when he assured me that it was the identical material with which Noah waterproofed his famous vessel, I felt my skep-

ticism growing weaker and weaker and was willing to admit that a material which would stand such a deluge for "forty days and forty nights" would very likely prove efficient in the light precipitations that we now have. Besides, I didn't like to question the judgment of such an illustrious waterproofing expert as Noah.

While listening to the rival claims of advocates of different methods of waterproofing, the engineer must not lose sight of the fact that waterproofing, at best, is but an expedient, and will not take the place of proper designing, nor correct poor construction. Water is a universal solvent and if not gotten rid of in time will seep through the ordinary materials of construction. The first requisite in the designing of any structure that must be water-tight is to provide means for getting rid of the water as directly and quickly as possible. In the numerous track-elevation bridges around Chicago, whatever the type of construction, the usual practice has been to slope the floor from the center to each end, carrying the water away back of the abutments, and right there is where much trouble has developed. Although one may place broken-stone filling and tile drains back of the abutments, when the surface ice and snow melts in the springtime and the filling back of the abutments is still in a frozen condition, the water does not escape freely, but piles up and eventually seeps through at the end of the bridge and flows over the face of the abutment. In bridges having supports on curb lines and in the middle of the street, whether of flat-slab construction or metal troughs filled with concrete, cracks are likely to appear where joints are not provided over these supports, and where joints are provided trouble is likely to be experienced in preventing the seepage of water.

In taking up, in a general way, the different methods and materials in use, I will first mention what is called the integral method. This method consists in adding a paste, powder, or lixiviating water to the concrete, mixing it with the cement, the mass of concrete as a whole or with the water. While doubtless any of these methods will make concrete impervious to water—as indeed can be done with ordinary concrete by careful proportioning and selection of aggregates, with subsequent care in placing—yet we know that monolithic concrete is apt to develop cracks from a variety of causes, and when that occurs there is likely to be a seepage of water through the mass. For that reason I have always preferred, for waterproofing engineering structures, what has come to be called the membrane method.

When I first took up the question of a suitable material for waterproofing engineering structures, I investigated the respective merits of asphalt and coal-tar pitch. The only instance of the use of the latter with which I was familiar had not proved very satisfactory, and I decided to use asphalt. At that time there were few, if any, artificial asphalts on the market, and I necessarily used a

natural asphalt. The structures then waterproofed are still in good condition. Since that time there has been extensive development of artificial asphalts from petroleum oils. In nearly all cases it is claimed that the artificial asphalts offered for waterproofing purposes have a Gilsonite base. Gilsonite is described by Mr. G. H. Eldridge in his article on "The Asphalt and Bituminous Rock Deposit of the United States" as "a black, tarry-looking substance of most brilliant luster, normally of absolutely homogeneous texture and exceedingly brittle." It is found in the Uinta basin, Utah, and takes its trade name from S. H. Gilson, an early prospector. It occurs in vertical veins in enclosing sandstone, and the veins vary from a knife edge to 30 in. in thickness. It is generally conceded that the origin of Gilsonite and other hydrocarbons may be traced to petroleum. Inasmuch as the sandstone in which Gilsonite occurs contains no trace of petroleum, it is evident that it was forced up from a great depth by an enormous pressure. Gilsonite is a very pure form of hydrocarbon and is used in a variety of ways in the arts and trades. It is used in varnishes and baking japans, insulating materials in electrical work, and for making mineral rubber, as well as in the artificial asphalts. Taking the amount of waterproofing asphalts that are turned out every year, I was interested in learning the total production of Gilsonite. I found from a reliable source that the total production last year was in the neighborhood of 30,000 tons and the previous year somewhat less. I am afraid that the Gilsonite base of our artificial waterproofing asphalt is a very thin one. Petroleum oil is not a uniform product, varying considerably at different places, and for that reason I have always been fearful that in asphalts made from petroleum oil we would not get a uniform product. However, I have had tested a number of artificial asphalts and found them to fill the following specifications very easily.

Material. 1. (a) Asphalt shall be used which is of the best grade, free from coal tar or any of its products, and which will not volatilize more than ½ of 1% under a temperature of 325 deg. F. for seven hours. (b) It must not be affected by a 20% solution of ammonia, a 25% solution of sulphuric acid, a 35% solution of hydrochloric acid, nor by a saturated solution of sodium chloride. It should show no hydrolytic decomposition when subject, for a period of ten hours, to hourly immersions in water with alternate rapid drying by warm air currents.

Range of temperature. 2. (a) For metallic structures, exposed to the direct rays of the sun, the asphalt must not flow under 212 deg. F. nor become brittle at 0 deg. F. when spread thin on glass. (b) For structures underground, such as masonry arches, abutments, retaining walls, foundation walls of buildings, subways, etc., a flow point of 185 deg. F., and a brittle point of 0 deg. F. will be required. (c) A mastic made from either grade of asphalt

by mixing it with sand in the proportion of one of asphalt to four of sand, must not perceptibly indent, when at a temperature of 130 deg. F. under a load of 20 lb. per sq. in. It must also remain pliable at a temperature of 0 deg. F.

In asphalting a metal surface it is imperative that the metal be cleaned of all rust, loose scale and dirt, and if previously coated with oil this must be burned off with benzine or by other suitable means. The metal surface must be warm to enable the asphalt to adhere to it, and the warming is best accomplished by covering it with heated sand which should be swept back as the hot asphalt is applied. When waterproofing concrete structures it is very necessary that the surface be thoroughly brushed with wire brushes to remove all loose particles and get rid, as far as possible, of what the French engineers call "laitance." It should then be coated with a liquid asphalt primer, and I believe that better results will be obtained if, just ahead of the application of this primer coat, the surface is swabbed with gasoline.

I am not an advocate of felts or burlaps for ordinary waterproofing. I believe that an ordinary concrete surface, whether in a slab bridge or an arch, needs nothing but an application of a primer coat of asphalt and then a coat of liquid asphalt, after which a hot sand mastic, composed of one part asphalt to four of sand, can be applied with hot smoothing irons. On top of this it has been my practice to put on a swabbing coat of hot asphalt and then to cover the whole surface with washed gravel, particularly where rock ballast was to be used. Over joints and ends of bridges it may be necessary to use burlaps for the added strength they give the asphalt in taking care of any slight movement. However, in cases of expansion joints, where any defined amount of movement is to take place, I believe that special means, such as copper flash joints, should be used. Burlap is a vegetable fibre and if used should be thoroughly saturated in a bath of hot asphalt of such temperature that it will not char or destroy the fibre. To apply asphalt to raw burlap in the field I think is wrong. If the asphalt is hot enough to penetrate the fibre, it is likely to be so hot that it will char or destroy it, and if the asphalt is not hot enough one gets only a surface coat.

I would like to repeat what I have previously said about the necessity for so designing the structure that the water can be disposed of as directly as possible. If more care is taken in designing, elaborate or expensive forms of waterproofing would be unnecessary.

Asphalt has no affinity for water, and all surfaces that are to be coated with asphalt should be as dry and clean as possible.

The methods I have used in preparing the asphalts are as follows:

The asphalt should be heated in a suitable kettle to a temperature not exceeding 450 deg. F. If this is exceeded it may result in "pitching" the asphalt. Before the "pitching" point is reached the

vapor from the kettle is of a bluish tinge which changes to a yellowish tinge after the danger point is passed. If this occurs, the material should be tempered by the addition of fresh asphalt. The asphalt has been cooked sufficiently when a piece of wood can be put in and withdrawn without the asphalt clinging to it. Care should always be taken not to prolong the heat to such an extent as to pitch the asphalt. Should it become necessary to hold the kettle for any length of time, bank or draw the fire, and introduce into the kettle a quantity of fresh asphalt to reduce the temperature.

There is a wide difference between the requirements for water-

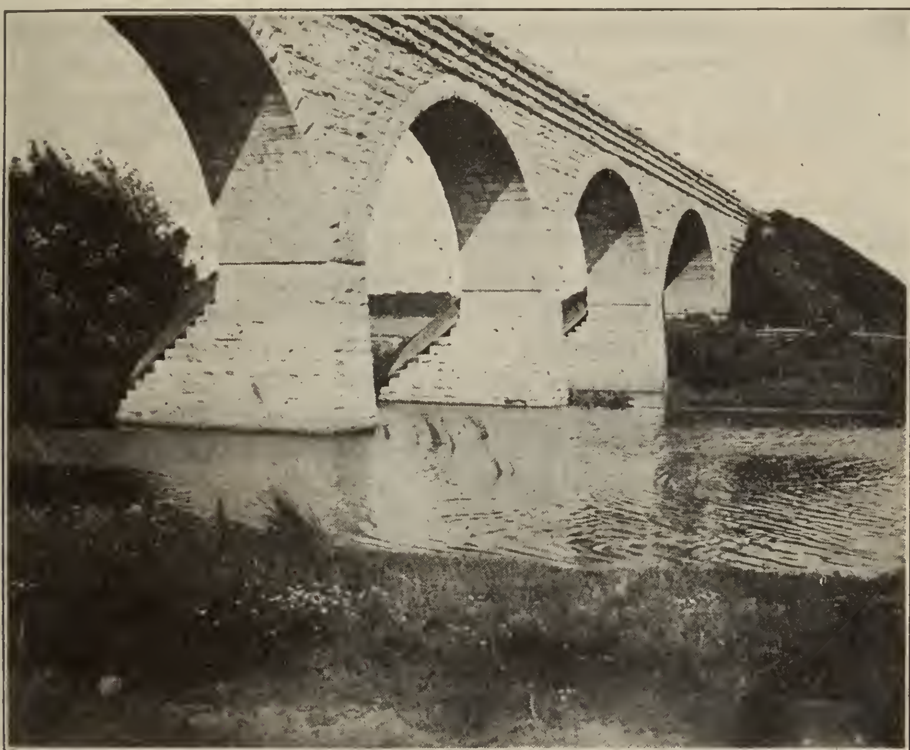


Fig. 1. Bridge over Turtle Creek, near Shopiere, Wis.

proofing to take care of ordinary rain water, or water-proofing where it is necessary to take care of the hydrostatic pressure of a head of water. In the latter case felt and burlap mat properly reinforced with concrete may be necessary.

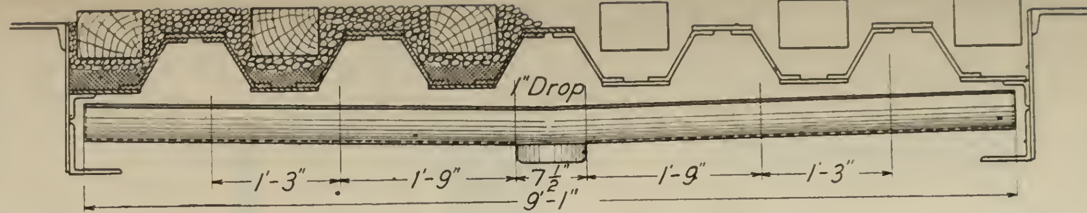
Figure 1 is a view of a bridge over Turtle Creek, near Shopiere, Wis., on the Chicago & Northwestern Ry. This bridge consists of five 50-ft. arches and was built in 1869 of Joliet and local limestones. The seepage of water through the ring and parapet walls reached such a stage that it seriously threatened the life of the structure. In 1887 this arch was uncovered, and the top thoroughly waterproofed with California asphalt. Three years ago I removed the filling and took up some of this natural asphalt, and

found it in first-class condition. The waterproofing of the arch at this time prevented any further leakage, and unquestionably prolonged the life of the structure. I have waterproofed a number of old stone arches that were showing signs of disintegration due to the lack of drainage. In 1896 a couple of 30-ft. arches over streets in the town of Janesville, Wis., were in such condition that it was a question whether they should be rebuilt or not. These arches had been built in 1864 of limestone with lime mortar. Inasmuch as the double-tracking of this portion of the road was contemplated some time in the near future, it was desirable to carry these arches as long as possible. They were uncovered and thoroughly waterproofed with asphalt. This prevented any further deterioration from the seepage of water, and in 1906, over ten years after the waterproofing was applied, when these arches were replaced by double-track concrete arches, the asphalt was found to be in excellent condition and a part of it was used in waterproofing the new arches.

Figure 2 is a view of the three-track bridge over Main street, Rockford, Ill. This bridge was built in 1893, and waterproofed with California natural asphalt. During the eighteen years it has been in place there has been no complaint regarding the dripping of water or leakage from the bridge, although it is over the principal street in Rockford. I attribute this largely to the fact that the water is drained from each floor trough into drainage troughs and carried by pipes through the abutment and outside of the dump. This is one instance of getting rid of water as directly and as quickly as possible. It avoids the trouble that is usually experienced at the end of the bridge where the drainage is carried from the center to each end. The only trouble experienced with these troughs is from birds building their nests in them during extended dry spells. These drainage troughs have been renewed once since they were first installed. In later work, troughs for a similar purpose were made of much heavier material. The locomotive stands on this bridge while discharging and taking on passengers at the Rockford station, and I have seen locomotives with their waste water cocks open pouring large quantities of water on this floor, which was carried off directly and quickly without any trouble.

Figure 3 illustrates a ballasted, very shallow floor bridge over Vine avenue, Highland Park, Ill., built in 1902. It was necessary to provide a water-tight floor at this point, and this type of floor was adopted. It has drainage troughs, and instead of carrying any of the water back of the abutments it is actually carried down in front of the abutment through troughs and down spouts. These troughs can be so arranged that it would be impossible for any trouble to occur from birds building their nests and stopping the troughs.

Figure 4 is a view of a subway on what is called the Kinzie street track elevation. You will note in this case the water is carried



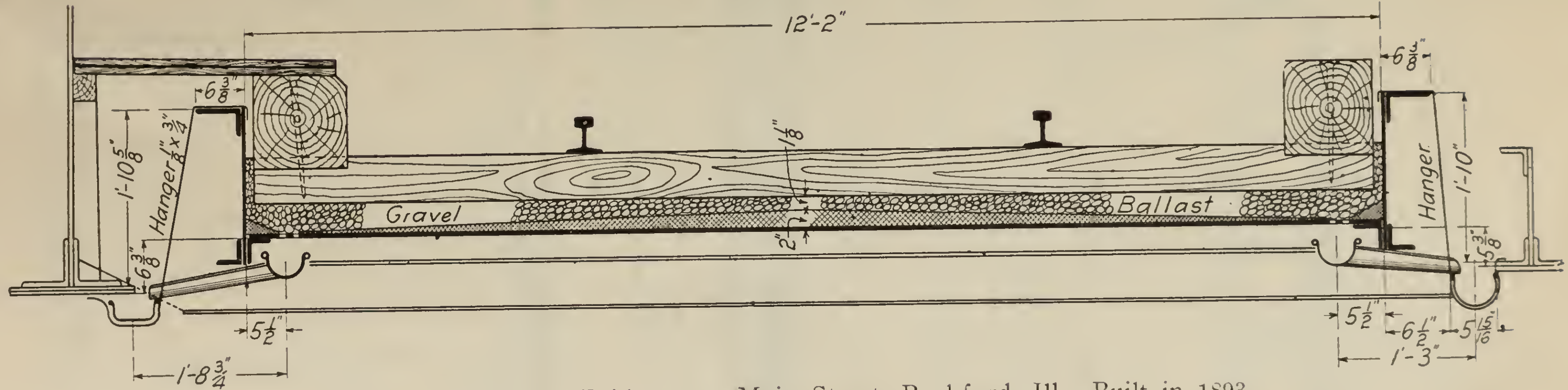


Fig. 2. Section of Bridge over Main Street, Rockford, Ill. Built in 1893.

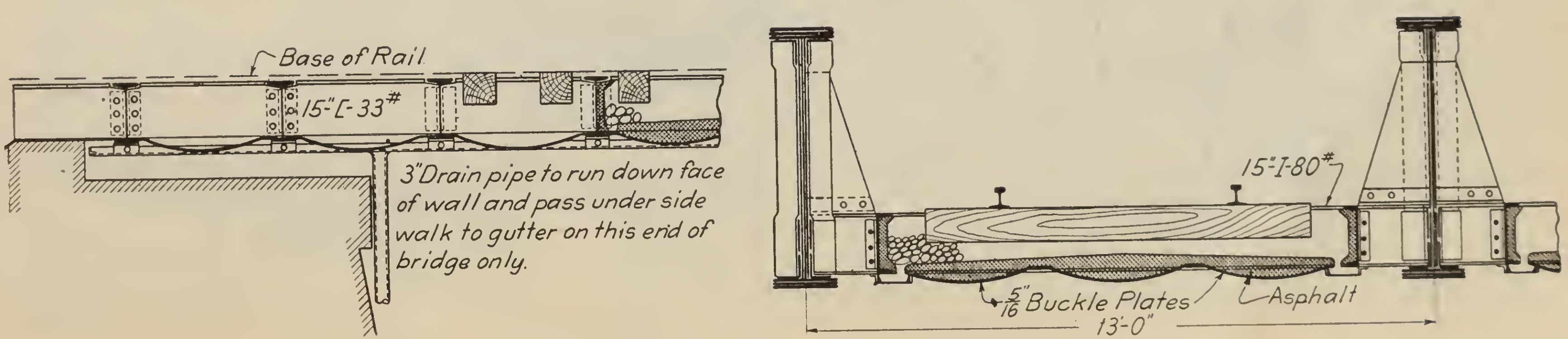


Fig. 3. Ballasted, Shallow Floor Bridge in Highland Park, Ill.

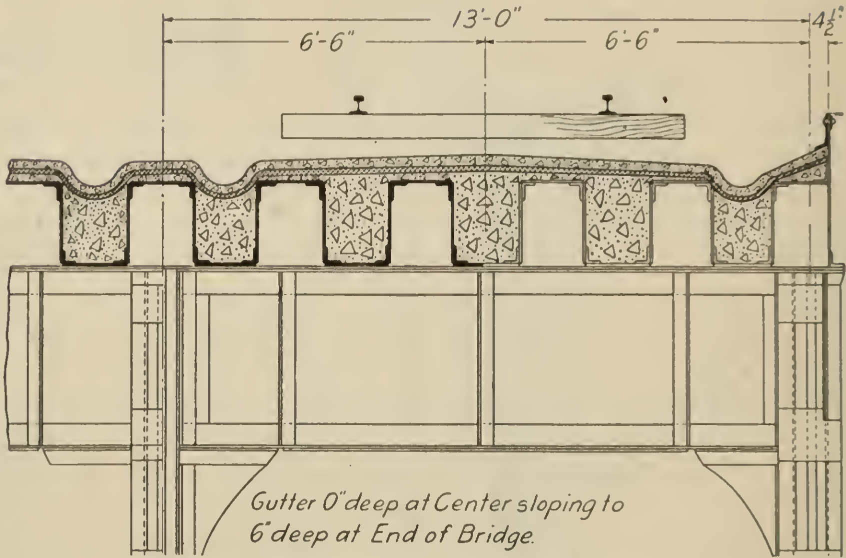


Fig. 4. Section of Subway Over Kinzie Street, Chicago.

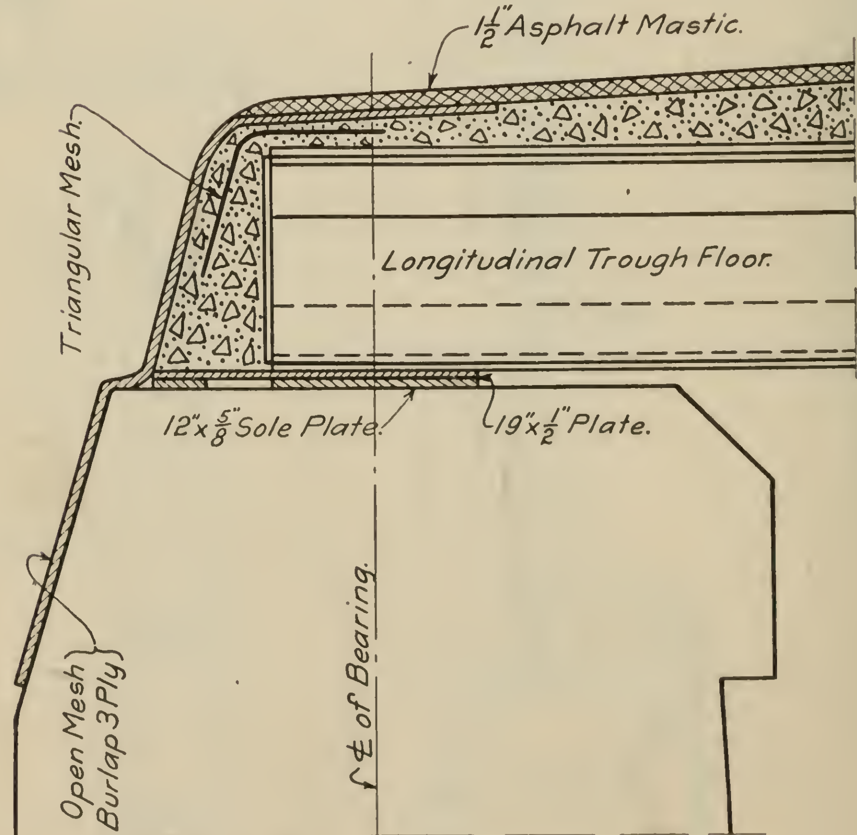


Fig. 5. Proposed Treatment of the Ends of Subways.

from the center of the subway to each end. A somewhat different method than I usually employ was used in waterproofing this bridge. The asphalt is imported mastic fluxed with Trinidad and Bermuda, and the asphalt mastic is covered by a layer of reinforced concrete. This work was done in 1905, and has proved very satisfactory, with the exception that there is some seepage of water at the ends of the bridge over the abutments. The method employed in sealing, as shown in this view, did not seem to be completely satisfactory, for the ends.

Figure 5 is a view of a proposed treatment of the ends of city subways to prevent the possibility of water getting through and flowing down the face of the abutment. This is an attempt to seal completely, by the use of burlap mat instead of the usual bent plate method that we have previously used.

The bridge over Wauwautosa avenue in the town of West Allis, Wis., is similar in construction to the Vine avenue structure. Last fall it was necessary to remove the bridge to make way for improvements at that point, and I was much gratified to see how thoroughly the iron had been protected by the asphalt mastic. A bridge of this type with such a shallow floor is subject to more or less vibration and deflection that would, under ordinary conditions, make it difficult to waterproof. However, in this case, when the bridge was taken apart and the asphalt removed there was no indication of any rust or seepage of water through or under the asphalt.

While my experience has been confined mostly to asphalt as a waterproofing material, yet I endeavor to keep myself in a receptive attitude and am anxious to learn of materials and methods other than I have described. I intend this spring to experiment with coal-tar pitch and felts to enable me to form an opinion of the durability of this method.

Discussion.

Chester B. Lewis, ASSOC. W. S. E.: I have often noticed, in another type of structure (building work) a common specification is that the foundation shall be damp-proofed with an asphalt compound a certain number of inches above the earth. Immediately above that is laid brick masonry with ordinary mortar joints. I have sometimes wondered whether any real benefit is gained. What is the use of carefully waterproofing one part of a structure with asphalt if there is another part, say 4 in. above, of nothing but lime mortar masonry?

Mr. Finley: Apparently there is no necessity for this specification. Anything above the ground line would be merely a damp-proofing to prevent dampness, from capillary action.

Louis J. Hotchkiss, M. W. S. E.: Few of us have had Mr. Finley's wide experience in waterproofing-work and I have listened to his paper with much interest. While I heartily agree with many

of his ideas, I have reached quite different conclusions on several points.

I have had experience in the track-elevation waterproofing proposition and have found it a difficult one. Numerous waterproofing experts have called on me, some advocating natural asphalt, some artificial asphalt, and some coal tar. Naturally, each thinks he has the best material there is for the purpose, and it is not easy for the engineer, with the present information on the subject, to decide between them. The question is one of judgment in selecting the material best suited to the work in hand, and of good workmanship in putting it in place. There is merit in all of these materials, but good results cannot be secured with any of them unless they are carefully placed, under favorable weather conditions. Work should not be done during rainy or cold weather.

The author seems to regard a membrane as unnecessary and in the particular cases illustrated has had good success without it. In these cases, however, the mastic is pocketed between the beams forming his floor system, and the separate sheets are quite thick; or it is covered and protected by a considerable depth of earth. Our work has been on flat slab concrete construction where large areas have been covered with a comparatively thin sheet of mastic, with only a few inches of protecting ballast. Under these conditions we have not been able to secure a mastic which will not crack, and we regard a membrane of felt or burlap under the mastic as essential, the office of the mastic being to protect the membrane from injury.

The author objects to the use of plain burlap as a membrane, and thinks it should be saturated before using. This is a bone of contention among engineers as well as among waterproofing men, and I disagree with him on this point. I have seen samples of saturated burlap, which, after lying around the office a few months, were so brittle they could be easily broken. The material is also rather stiff and correspondingly difficult to lay.

We have used only plain eight-ounce, open-mesh burlap laid three ply the first season and five ply thereafter. Most of the work was done during the summer, but it was continued the first season until the weather had become quite cold. Leaks developed in this work later, and samples were cut out to determine the cause. It was found that the mastic was badly cracked, the lower layer of burlap not saturated with asphalt, and the second layer only partly saturated. The third layer, while well saturated, had not in itself been sufficient to prevent the water from coming through the cracks in the mastic.

In order to determine this question of saturation we cut out samples of the work done in warm weather. No leaks had developed, and every layer of burlap was completely saturated and in first-class condition. From this experience I am convinced that work

of this character should be done in warm weather or where the structure can be kept warm by artificial means.

The author also spoke of the adhesion of the waterproofing material to the surface to be waterproofed, and I infer that he regards this as a matter of importance. We have disregarded it entirely, and have endeavored to make the waterproofing tight around the edges of the structure. At the right of way lines it has been carried up on to the parapet walls, turned into grooves and protected with a covering of concrete. It has been carried down over the back of the abutment and covered in a similar manner. I think this method is fully equal to the other in results and it is much easier. In many instances it is impossible to secure adhesion under working conditions. No asphaltic preparation of which I have knowledge will stick to wet concrete. Under track-elevation conditions, as well as many others, a given track can be put out of service for only a limited time and the work must be done with expedition. If it rains the night before waterproofing is to be done, you cannot wait for the deck of your bridge to get dry, and if waterproofed while damp, adhesion cannot be expected.

Waterproofing is still to a considerable extent experimental, and while engineers will probably continue to the end of the chapter to disagree on methods and materials, we are all looking for ways to improve our work and will welcome any man who can suggest something along that line.

Mr. Finley: I fully appreciate what Mr. Hotchkiss has said.

My objection to the idea of waterproofing where it is sealed around the edges, is that if there is the slightest puncture, it admits water under the whole surface, and water that is covered up and not permitted to evaporate is bound to penetrate the concrete. It is quite possible to make asphalt adhere to concrete, and in so doing we remove the possibility of any opening that will admit moisture or water to the whole surface.

Mr. Hotchkiss said that my efforts were limited wholly to the troughs where asphalt is confined. I think he is somewhat mistaken in that, because my first attempt in that direction was on arches where the whole surface was exposed, and my endeavors were to make a covering that would adhere to and prevent the infiltration of water. In my first attempts to waterproof a concrete surface, I tried heating the surface, but found that this drew up the moisture. After applying asphalt in a number of such cases I found I could roll it up like a blanket. It was at that time that I conceived the idea of applying asphalt as a cold mixture. I mixed the asphalt with gasoline to hold it in solution and permit it to be applied as a cold mixture. At that time no one in the United States was supplying any such product. Today it can be obtained here in Chicago. The Kinzie street track-elevation has a large expanse of concrete surface protected by asphalt, and presents the

same condition and the same difficulties mentioned by Mr. Hotchkiss.

There seems to be a decided difference of opinion among engineers who are looking after this work, as to a membrane that is not a part of the body and a membrane which adheres to it. It seems to me it is better to make the mixture of asphalt, coal tar, or whatever it may be, adhere to the concrete as a whole than to consider it merely as a separate skin construction that must be sealed around the edges. While it is possible to make such a construction, yet if there is the slightest puncture of any portion of the skin construction it means an infiltration of water under the coat that cannot escape, and this will in time penetrate the concrete.

W. F. Steffens, M. W. S. E.: The subject of waterproofing is of considerable interest to the eastern railroads as well as to the western lines. On the Boston & Albany Railroad we try, as far as possible, to construct solid floors for bridges over highways, eliminating thereby the maintenance of canopies over the roadways beneath, or the planking of the ties to prevent water, oil, or cinders from locomotives falling to the street below. The traffic conditions are such that it is necessary and advisable to erect the new bridges at the side of the old, and subsequently roll the new and old superstructures laterally so that the new work occupies final position; the old structure can then be dismantled at leisure. This means that the structures are subjected to some wrenching stresses that must be taken care of, as far as possible, in the design.

One form of structure that we think favorably of is that having steel I-beams entirely embedded in a solid slab of concrete. Mr. Finley may question the general design of such structures, but we consider them efficient, as they provide a solid mass to receive the blows of unbalanced locomotive drivers or flat wheels; or, in other words, they provide an anvil practically free from vibration. More especially, however, is freedom from noise from passing trains, and the entire elimination of maintenance, secured by these structures.

In erecting smaller types of such slabs, we have found it desirable to divide the work into separate sections for each track, erecting these sections of width sufficient to hold the ties temporarily before the ballast is placed. Later, the additional beams necessary to give the final width of the structure are placed, and the concrete and waterproofing work is finished. In the earlier bridges of this type, the slabs were found perfectly water-tight, but in the joint betwen the original slabs and the concrete placed at a later date, a small leak developed. The type of waterproofing for these structures has, up to this time, been a heavy coating of coal-tar pitch. We have been able to eliminate the leaks mentioned by providing a channel in the joint formed, into which soft pitch or asphalt could be subsequently poured, finally applying the finishing coat over the entire surface.

For larger structures we have built the slabs as a unit for the entire number of tracks to be carried, afterwards rolling into place the single slab. For these larger structures we have used, for waterproofing, a membrane consisting of alternate layers of felt and asphalt, with a protection course of brick laid in hot asphalt. In moving a large mass of this character, as a unit, on rollers, unless the track supporting the rollers is absolutely rigid, there is a tendency for the slab to be separated and to tear the waterproofing membrane. Experience has shown that it will be desirable in this character of work to design the structure with a convenient number of joints filled with a soft asphalt and capped by a membrane of something more elastic than the usual felts. The waterproofing experts are interested in helping us to find an elastic membrane that will fulfill the purpose of affording a slight movement at these joints.

In waterproofing the smaller slabs with coal-tar coating, we have found it practically impossible to secure a bond between the concrete and the pitch in cold weather. It is absolutely necessary that the temperature of the surface to be coated be sufficiently high to afford a bond, and it is impossible to secure the bond if the sur-

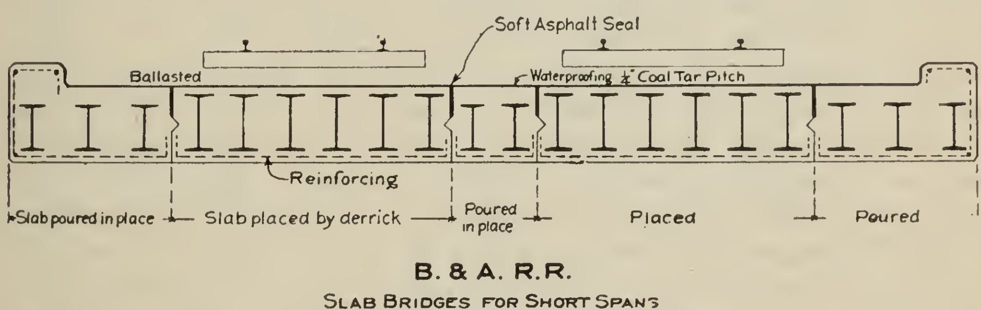


Fig. 6. Concrete Slab Bridges, B. & A. R. R.

face is at all damp. In some cases it has been possible to heat the surface by pouring on gasoline and igniting it. In other cases it has been necessary to delay the work until proper conditions of weather and temperature could be secured.

In the case of the large bridge now under construction at Worcester, Mass., and located on a considerable skew, it has been found necessary to provide expansion joints liberally at critical points. The question of waterproofing these properly has been quite a problem. We are elevating the surface of the slab at these points as far as possible to prevent water reaching them. The waterproofing membrane will be depressed as it passes the expansion joint, and the pockets thus formed will be filled with a soft asphalt. The waterproofing membrane will be reinforced by using thin sheet lead between the courses of felt or fabric.

We try to eliminate the trough floor, if it is at all possible to do so. The alternate freezing and thawing incident to the eastern climate renders it troublesome to conduct the water away from

structures of this character in a satisfactory manner by means of drainage troughs placed beneath the track troughs.

F. E. Davidson, M. W. S. E.: I should like to have some one tell us how he would waterproof a rubble stone masonry wall, under a hydrostatic head of about 5 ft.; for instance, the basement wall of a heavy manufacturing building, where it is impossible to get at the outside of the wall. If one can get at the outside of the wall, the problem is an easy one, but where this is not possible the problem becomes difficult. I know of some problems of this kind that have been solved successfully both by the asphalt experts and by the ironite experts. I have never used any coal-tar products, as I am afraid of them.

Mr. Finley: That seems to be one of the heaviest problems we have.

J. W. Pearl: I think I can answer Mr. Davidson's question. If he will start a man to work on that wall with plain Portland cement wash and a whitewash brush, washing the wall at a temperature that will dry the coating, and keep the man at work on the wall, it will be waterproofed perfectly. In my work I have accomplished waterproofing of that kind in an intake well for a waterworks plant built of porous brick, through which water came, though not in streams. If there are any streams coming through the wall, that give trouble, drive in a pine wood plug; then put a man to work with a wash of Portland cement. This will, in the first place, form a thin coat of plaster. The wall will commence to dry at one part or another, and as the application of the wash is continued, the dry spots will enlarge until the wall is waterproofed completely. I obtained such results under a head of 12 ft. of water.

A Member: About how thick was the coat of Portland cement when the work was finished?

Mr. Pearl: I do not know exactly, as I did not break into it; probably 1-16 in. I had the work to do and I accomplished it. The wall (only 12 in. thick) was absolutely tight and dry inside with a 12-ft. head of water right next to it outside.

It occurs to me, though, in connection with the subject of waterproofing concrete, that what has been discussed here this evening has developed more into the question of closing cracks in concrete than waterproofing concrete. In the matter of drainage that has given trouble, I have noticed that according to my understanding it has been where the drainage has been carried down through a fill of frozen ground. It is not surprising that trouble develops. If the drain water is the result of the effects of the sun, carry it on the surface where the sun will have a chance at it. I do not think there will then be any trouble. Of course, if there are cracks, one is liable to have trouble, but the matter of waterproofing concrete *as concrete* is a different proposition from closing cracks.

President Armstrong: I thing almost all engineres are generally agreed that the subject of waterproofing is not so much in the material as it is in the execution of the work. As has been mentioned this evening, the engineer is frequently handicapped in his work of execution by the conditions under which he has to work. In waterproofing a structure of a large number of tracks side by side, very often he can only get the use of one track at a time. We have found that one of the great sources of trouble in waterproofing a large area covered by a number of tracks occurs along the joint between tracks. For instance, you may have a number of tracks say 13 ft. apart. You get just one track at a time to work on. You have to work on this strip between tracks, sealing the waterproofing to that you laid first. In the meantime, the men are walking over it; it gets covered with a film of dust and dirt, which, if not carefully cleaned off before the next layer of waterproofing is put on, forms a seam where moisture will get through. That we find to be a fruitful source of failure in waterproofing.

As far as waterproofing concrete is concerned, I think we are mostly agreed that concrete itself does not need much waterproofing; it can be made practically waterproof without the addition of any material; but the problem is the waterproofing of the cracks which are bound to occur in every concrete structure. This is particularly true in some of the types of bridges that have been illustrated here this evening. Take the case of bridges of two or more spans, supported by bents or piers. There will be deflection in the spans, which will inevitably result in a crack in the concrete over the bent or support. Then the question becomes one of applying a material that will remain intact over that crack. I am not exactly in accord with Mr. Finley in regard to the use of a mat of some kind in the waterproofing. It may not be necessary over the body of the span or over the slab or whatever it may be, but it appears to me that it is absolutely necessary that something of that kind be employed over the support where the crack is apt to occur.

I am also not exactly in accord with Mr. Finley in the matter of sealing the waterproofing to the concrete, especially over supports. Wherever the crack occurs, there will be a movement first apart and then closing up as the load goes over the structure. There will also be a tendency for the crack to widen in cold weather, and if the waterproofing is sealed absolutely to the structure, the stretch must occur in the width of this crack; whereas, if it is not absolutely sealed, the stretch may be distributed over a greater length. It seems to me that better results would be obtained if the mat were not sealed absolutely to the concrete underneath at these points.

W. S. Babcock (Barrett Mfg. Co.): In the East some years ago, when the matter of waterproofing the bridge viaduct at Providence, R. I., came up on the New York, New Haven & Hartford

Railroad, the engineer of bridges used the following specification, this being the first application of the form of waterproofing, having a core of felt reinforced with cotton drilling:

STANDARD SPECIFICATION FOR WATERPROOFING OVER CONCRETE BRIDGES

The concrete shall be smooth and perfectly graded to carry water to outlets.

There shall be used four thicknesses of Specification Felt, one thickness of Tartex and a sufficient quantity of Specification Pitch to provide for the moppings specified. The pitch shall have a melting point varying not more than 5 degrees either way from 125 deg. F.

The material shall be applied as follows:

First—Coat the concrete with hot pitch mopped on uniformly to insure the sticking of the first ply of felt.

Second—Over the entire surface lay two plies of Specification Tarred Felt, lapping each sheet 17 in. over preceding one, mopping with Specification Pitch the full 17 in. on each sheet, so that in no place shall felt touch felt.

Third—Coat the entire surface uniformly with Specification Pitch.

Fourth—Lay one ply of Tartex Felt, lapping the joints 2 in., and lay with cotton surface face downward.

Fifth—Coat the entire surface uniformly with Specification Pitch.

Sixth—Over the entire surface lay two plies of Specification Tarred Felt, lapping each sheet 17 in. over preceding one, mopping with Specification Pitch the full 17 in. on each sheet, so that in no place shall felt touch felt.

Seventh—After the last ply of felt has been laid, give the surface a heavy coating of pitch mopped on uniformly.

Materials required per 100 sq. ft, for the above: 400 sq. ft. Specification Tarred Felt, 100 sq. ft. Tartex, 240 lb., Specification Pitch. (Allow 40 lb. of pitch for each mopping per 100 sq. ft.)

Note—Engineers vary as to the advisability of coating or sprinkling the concrete before the first layer of felt is applied, some contending that it is better to have a solid mopping of pitch, and others, only sufficient to hold the felt in place while it is being laid, thus leaving the blanket of waterproofing free of the concrete during expansion and contraction. All this depends upon the amount of vibration the bridge is subjected to. As a protection against the ballast, we advise the use of bituminous binder on areas exceeding 100 sq. ft.

Bituminous Binder for Bridge Waterproofing Protection.

The binder shall consist of gravel, sand and coal-tar pitch.

The gravel shall be from 1/8 to 5/8 in. in size.

The pitch shall have a melting point varying not more than 5 degrees from 125 deg. F.

They shall be mixed together in the proportion of three parts of gravel, two parts of sand, and one part of pitch in volume. The sand and gravel shall be thoroughly dried, and all materials heated sufficiently to permit thorough mixing, but in no case shall the temperature exceed 300 deg. F.

This mixture shall then be spread over the surface to the required thickness and compacted either by tamping or rolling, and given a mopping of coal-tar pitch, the same as is used in the mixture.

If ballast is to be applied directly on the bituminous binder, it

should be 2 in. thick. If there is sufficient space to allow for a sand cushion above the bituminous binder, 1½ in. of binder is sufficient.

Note—One mix requires: 1 cu. yd. gravel, 2-3 cu. yd. sand, 535 lb. pitch.

If the mix does not require all of the pitch, use the balance as a top dressing, pouring it over the bituminous binder.

Note—We advise the use of bituminous binder as a protection only on areas exceeding 100 squares. On surfaces smaller than this we advise a brick or concrete protection with proper allowance in this protection for expansion and contraction. The bituminous binder must not be used upon surfaces having an incline exceeding ½ inch to the foot. In case the bituminous binder is used on flat surfaces where the surface of the concrete is graded at the sides of the bridge, these sides must be protected by either brick or concrete, preferably brick.

The origin of the reinforced felt, which at the present time is called Tartex, was due to the desire of the Public Service Commission in New York City to find a suitable woven fabric, for use in subway waterproofing, having a high tensile strength. This felt was too expensive to use on the subway, but when used in bridge waterproofing as a core between four plies of 14 to 16-lb. felt, it proved to have sufficient tensile strength to hold the whole mass of waterproofing in a body.

On this first job of waterproofing at Providence, the viaduct was sprinkled just enough to hold the first layer of felt in place; then the alternating coatings of pitch and felt were laid, and the bituminous mastic, of a thickness of 2 in. (as per the above specification) was placed over the entire flat surface.

Since that time there have been a great many bridges waterproofed according to this specification, namely:

Worcester viaduct, N. Y., N. H. & H. R. R.

Ninety-six bridges on the Long Island improvements, Long Island R. R., about 40 of which are completed.

Bridges on the Indianapolis division of the Penna. R. R. between Indianapolis and Columbus.

Some bridges on the Lehigh Valley R. R.

Some bridges on the Southern Railroad.

Large area of concrete floor used as a storage yard for the Interborough Rapid Transit Company at 240th street, New York.

In the case of bridges of areas of less than 100 squares, it has been the custom to use hard burned bricks laid in coal-tar mastic, or 3 in. of concrete with a galvanized iron wire reinforcing as a protection against the ballast, and it is in every way as good as the bituminous binder. The use of the bituminous binder on large areas, of course, adds a percentage of waterproofing material to the blanket composed of coal-tar pitch, tarred felt and Tartex. The reason it is not advisable to use the bituminous binder on small areas is that it is quite expensive to get the materials and have them taken care of, as it is necessary to heat the gravel, the sand and the

pitch, and the additional value is not sufficient to warrant the expense.

Many of the engineers in the East who have used this method of waterproofing bridges differ in their opinions regarding the sticking of the blanket of waterproofing to the concrete, or leaving it free, for the reasons as stated by Mr. Finley, that if cracks form in the concrete, as they are bound to—hair-line or greater—and the whole blanket is free of the concrete, the expansion and contraction will be taken care of, and the strain will be distributed over the whole area instead of at any one particular point of the blanket.

About four years after the waterproofing of the Providence viaduct, the writer saw Mr. Wm. H. Moore, bridge engineer, and asked him regarding the condition of this work. Mr. Moore replied that there had never been a leak upon this large expanse of waterproofing.

The storage yard of the Interborough Rapid Transit at 240th street, where there are about 500 squares of waterproofing, has developed no leaks up to the present time.

On the Long Island Railroad, the report from this work shows that on the forty bridges which are waterproofed there have been no complaints, and no leaks have developed.

In closing his remarks, the writer would state that the form of waterproofing referred to had its inception in June, 1908, and has not once proved a failure as far as the writer can ascertain. In every case it has been satisfactory. Previous to this, the use of coal-tar pitch and felt did not give good satisfaction in bridge waterproofing, as it seemed to be lacking in sufficient tensile strength.

Norman Malcolm (Standard Asphalt & Rubber Company): I believe I am speaking for all at the meeting when I express my appreciation both of Mr. Finley's paper and Mr. Hotchkiss' discussion. From my experience in waterproofing I will say that one of the particular points from which we can derive benefit from the paper is in the emphasis placed on the proper design of a structure to accommodate it to waterproofing, and proper and adequate drainage to take the water away. I think Mr. Hotchkiss' point is very well made in the emphasis that he placed upon good workmanship under reasonably favorable conditions. We all know that poor work may be the result of poor workmanship or of poor material, and that fair work may be accomplished with care, even with an indifferent material; also that there may be indifferent results even in the use of considerable care with indifferent material. There is, of course, a great difference of opinion among engineers as to the use of a primer or cemented membrane as against the sheet or loose membrane, particularly on flat surfaces, and good results have been accomplished with both in certain instances. But

I agree with the author that it would be better to provide something which would cement the waterproofing membrane closely to the concrete to prevent the spread of water underneath. The argument which is advanced in opposition to the membrane being cemented to the concrete, is that it is thereby renderd a part of the concrete, and cracks in the concrete are likely to be carried through the waterproofing membrane unless the waterproofing has, as mentioned, those qualities of elasticity which will enable it to bridge over the cracks which are likely to occur in concrete. Engineers have profited from the experience of both Mr. Finley and Mr. Hotchkiss, because both the C. & N. W. Ry. Co. and the C., B. & Q. R. R. Co. have done a great deal of waterproofing work, and have, I am pleased to say, accomplished unusually satisfactory results with the materials they have used.

There is one point which Mr. Hotchkiss did not bring up, in regard to waterproofing joints or cracks, which I think is of considerable importance. He may remember having his attention called to the column lines or junctures between street and sidewalk slabs. In some of the work on the C., B. & Q., and other railroads, it has been found that in order to provide satisfactory waterproofing over this joint, which was subjected both to vibration and movement between the slabs, it has been necessary to adopt the system of laying the membrane at such places over a piece of pipe 1 in. or 1¼ in. in diameter and afterwards withdrawing the pipe as the waterproofing work progressed. This leaves a loop which can then be crushed down flat on the surface so as to form no obstruction to the escape of the water, and be thoroughly cemented or saturated with a waterproofing material, thereby supplying perhaps one or two inches of surface membrane which can, when displacement takes place at the joint, stretch out and overcome the difficulty. The conclusion I would draw from the experience with waterproofing work is, that it is by no means (and I think I express the opinion of most of us who have had to do with it) an easy problem to do effective waterproofing. It requires both careful design and workmanship and also, I think, the use of the best possible material obtainable. It is not only annoying to have waterproofing work ineffective, but it is particularly so on railroad bridges, where it is expensive to have to tear up tracks and replace ineffective waterproofing. In many cases the cost of doing this would be many times the cost of doing the work in the best possible way with the best. material obtainable during the original installation.

J. N. Canavan (with C. W. Humphrey): It seems to me the question of waterproofing is too broad a subject to discuss on general lines, inasmuch as every man has an argument to suit a particular structure with which he is most acquainted. For instance, a discussion on structures subject to vibration, such as railroad bridges, which have problems not in any way connected with

the waterproofing of retaining walls, deep wells and like structures, could occupy the whole evening. I believe that some are apt to use an argument for waterproofing a large flat slab on top of a subway that we know is not going to bob up and down, and apply that argument as an answer to a problem where excessive vibration exists and then say they were successful where others were not.

Referring to the use of burlap, I want to put a sort of damper on the use of burlap at all. The talk this evening is on waterproofing of engineering structures, so it may seem a little off the subject to speak of a cooling tower; nevertheless, this is a waterproofing proposition that was put before some makers of treated burlap. In this case condensing water of a temperature of a little over 100 deg. F.—which is usual with a 28-in. vacuum in a condensing system—runs over treated burlap curtains, hanging vertically. The curtains were to be treated with one of the various compounds, or one of the ready-treated burlaps was to be used, whether Simplex or any other kind. Two were tried, and it was found that at the end of eight months, at the maximum, one could push his finger through either of them, the coating of asphalt or other material being nearly as thick as when originally applied. Experiments had also been made with ordinary tar, applied hot. The remark of the next man who came along was: "You burnt your fibre." Then some one else came along with a product that we applied cold. It failed in the same way. This showed that the action of water slightly warm and the different products used in the treatment of the burlap formed something that destroyed the fibre of the burlap. So we are still waiting for some one to step up and waterproof burlap on a straight, no-head, 100-deg. F. water proposition.

I therefore think the proposition of using the burlap membrane is wrong, from the fact that one must have some mastic that will do the work of stretching without cracking and not trust to the membrane, because the crack is where the water comes through, quickly destroying the burlap. Therefore, at present I do not think there is a membrane made which can cover a joint between slabs and waterproof it. That must be done with either copper, a sheet of lead, or something in the nature of metal, and not burlap.

Speaking of membranes, I believe that most of the gentlemen here are thinking of a fibrous material such as burlap. The speaker of the evening has said he is not quite clear as to what its limitations are, and he has also put a doubt in my mind. I do not think the membrane method is a success, especially on vibrating structures. I say this by reason of my experience.

Mr. Lewis: The point was raised that the question was not one of waterproofing concrete but of filling up the cracks so that water could not get through them. In a large number of structures the concrete is not plain, but is reinforced with rods. I would like

to have some one who has had more experience than I have, give his experience in using a sufficient amount of steel reinforcing rods to prevent cracks forming.

President Armstrong: In large railroad structures it is almost an impossibility—an impracticability, at least—to reinforce concrete so that there will be no cracks over a line of supports. It would not be good engineering to undertake to do it. It would be better to leave it open and allow the concrete to crack or leave a joint there and then provide some means of keeping out the water. Of course, in the lighter structures, where the stresses are not so great as they are in heavy railroad structures, it is practicable to reinforce the concrete so that the reinforcement will take up the expansion and prevent cracks.

Mr. Lewis: The structure I had in mind was a thin wall between two tanks that it was necessary to reinforce in some directions for other reasons.

President Armstrong: I think in that case the wall could be reinforced so that there would be no cracks but the fine hair cracks, and a thin waterproofing would take care of those very easily.

Mr. Davidson: I have another problem in waterproofing—with a saw-tooth form of roofing, how is one to exclude the water from the valleys after heavy snows? If laborers are sent up to shovel off the snow, the roof covering, if of felting or even copper, becomes pierced with holes. If the roof covering is made of concrete, that may hold against walking over it, but how can the concrete be best waterproofed? .

Clifford Rihardson, M. Am. Soc. C E., (by letter): Mr. Finley was a pioneer in waterproofing engineering structures of the type mentioned in his communication; as evidence of which may be cited a previous paper, "Waterproofing Concrete Structures," to which he refers, delivered by him before the Cement Users' Association at Indianapolis, Ind., in January, 1905, and printed in the *Engineering News* of January 26, 1905, Vol. 53, page 95, which is well known to all engineers who are interested in the subject. In view of this, anything that he has to say will always receive careful attention and carry great weight. Mr. Finley, in the first part of his paper, states that "the first requisite in the design of any structure that must be water-tight is to provide means for getting rid of the water as directly and quickly as possible." There is nothing truer than this and it is something that is too often neglected, whether the structure is to be waterproofed or not. Only recently, where no provision was made for the removal of water collecting behind the concrete lining of a railroad tunnel in the East, which was not waterproofed, the water has forced itself through the more or less porous concrete, has saturated it, and freezing in winter has disintegrated it to an alarming extent. From

years of experience it appears that the only way to prevent this is the immediate removal of the water before sufficient pressure can arise to force it into or through the structure. Such a provision at points over supports where cracks generally are found will be an assistance in the prevention of leaks. This can be accomplished by flashing, as suggested by Mr. Finley, or a weeper, to the exterior of the structure, providing immediate relief. The strain on the waterproofing will thus be reduced.

If a membrane is used as an auxiliary it should be a saturated fabric and not a felt, for several reasons. A fabric can be fitted closer to the surface to which it is applied than a felt, owing to its greater pliability and because it is less liable to tear. It is very necessary, however, that the fabric should be carefully prepared. Many of those on the market are quite unsuitable for the purpose, owing to unsatisfactory methods of manufacture. The defects in such fabrics lie in two directions: *First,* burlap is a highly hygroscopic material and the water which it holds is removed only slowly on heating, especially if it is immersed in a thick and viscous bituminous material. *Second,* the fibre of which it is composed is readily injured by high temperatures, at least if continued for any length of time. For these reasons the preparation of a well-saturated burlap requires that it shall remain in the bituminous saturating material until all the moisture is removed, and that the temperature of the saturating material shall not be so high as to injure the fibre, although at the same time it is sufficiently liquid to penetrate the latter. All bituminous materials are not, therefore, suitable for saturating purposes. Those of a very high melting point, such as the blown-oil products, are unsuitable since they have too high a melting point to be safe and are too viscous, even when melted, to give a satisfactory penetration. On the other hand, materials which are too oily are unstable and undesirable. It is evident, therefore, that a desirable burlap can only be obtained from producers possessing not only the necessary skill, experience and plant for the purpose, but also using the most suitable and stable saturating materials. Whether a burlap is a satisfactory one, can be determined readily in the laboratory by examination as to whether it contains moisture, and the percentage and character of the fibre, after the removal of the bitumen with solvents. Burlaps should be of open texture and not too thick. Experience has shown that a seven-ounce fabric is more flexible and much superior to the heavier grades.

All that has been said of burlaps applies equally well to felts.

The author brings out a very important point in his paper,—the necessity of carefully cleansing the surface of concrete or metal before the application of waterproofing and of having it dry and warm, when possible. With cold surfaces the application of a coat of gasoline, before the use of the bituminous paint, may be a de-

sirable precaution with bituminous material of a certain character, but is not always necessary. In no case can the paint course be omitted with safety.

In regard to the use of Gilsonite in waterproofing materials, the author's statement that the amount that any one of them contains is very small, is correct, as far as it is a component of any of the bituminous substances of this kind which have as a basis blown-oil products. Where it is combined with a heavy asphaltic flux, from 30% to 40% is used, and a more desirable product obtained, of entirely different character from the blown-oil materials, with which not more than 5% to 10% of Gilsonite can be combined.

Referring to the author's specifications as given in the paper, the writer would say that, in his opinion, they call for a material of much too high a melting point, and on this account, necessarily, a very short material and one lacking in ductility and adhesiveness. A material of a lower melting point and one that is more adhesive possesses much greater self-healing properties; that is to say, of uniting if a crack forms in the concrete over which it is placed and, by any chance, fractures the waterproofing coating. It would consist of a fluxed native solid bitumen and would meet the following specifications:

1. *Asphaltum:* In order to demonstrate that the asphaltum is free from coal tar, its distillate, obtained upon destructive distillation, must be completely insoluble in dimethyl sulphate.

In order to demonstrate that the asphaltum is essentially a genuine natural asphaltum and not largely a petroleum residue, it shall have a specific gravity, at 77 deg. F., greater than unity, and shall not contain over 1.0% paraffine scale as determined by the Holde method.

2. *Purity:* In order to demonstrate the percentage of bitumen in the asphaltum and to regulate the uniformity of the material, it shall be soluble to the extent of at least 95.0% in carbon disulphide.

3. *Consistency:* In order to demonstrate that the asphaltum is of the proper degree of consistency it must, when tested for 5 sec. at 77 deg. F. with a No. 2 needle weighted with 100 grams, have a penetration of at least 7.5 mm. and not more than 10.0 mm.

4. *Viscosity:* In order to demonstrate that the asphaltum has a sufficiently low melting point and a degree of fluidity to be conveniently melted for use, and possesses suitable flowing and self-healing properties, it shall have a viscosity of not more than 10 minutes at 150 deg. F., as determined by the float test apparatus manufactured by Howard & Morse, Brooklyn, N. Y.

5. *Cementitiousness:* In order to demonstrate the cementitious or adhesive character of the asphaltum and to preserve the proper balance between its adhesive and cohesive qualities, such asphaltum shall have a ductility between 25 and 100 cm. at 77 deg. F., according to the District of Columbia standard.

6. *Stability:* In order to demonstrate that the asphaltum is of a sufficient stability to insure against loss of consistency upon being subjected to working heat, it shall meet the following test:

When 50 grams of the asphaltum are heated in a dish 2¼ in. in diameter for 7 hours at 325 deg. F., the loss shall not exceed 3%, and the penetration of the residue shall not be reduced more than 50% from its original consistency.

7. *Durability:* In order to demonstrate that the asphaltum is unaffected by water, a thin film of such asphaltum, when coated on glass and immersed in fresh or salt water at atmospheric temperatures for an indefinite period of time, must not disintegrate.

8. *Safety:* In order to insure safety of operation the asphaltum must not flash below 350 deg. F. when tested in the Cleveland cup.

9. *Standard:* Any asphaltum to be eligible for use under these specifications must be in all respects equal in quality to refined Bermudez lake asphalt, but whether the asphaltum is manufactured of refined Bermudez lake asphalt or otherwise, it shall not be considered as complying with these specifications unless it complies with each and all of the tests herein above specified.

This material is characterized by greater ductility and adhesiveness than are called for by Mr. Finley. It is, in the light of the writer's experience with such materials, much superior to any of the blown-oil or coal-tar preparations. There is no doubt that coal-tar is too brittle at low temperatures, too liquid at high temperatures, and too liable to change, and that the blown materials go to the other extreme, being too viscous, at high temperatures, and lacking in adhesion at all temperatures.

The asphaltic cement of the type called for in the specification given, is a happy medium. It is oily, cementitious, possesses self-healing properties, is readily melted and applied, and is not as brittle as coal-tar at low temperatures, nor as susceptible to high temperatures.

As an interest is expressed in the paper as to the character of the various bituminous materials which are used in waterproofing, and as explaining some of the previous statements of the writer, the following may be found to cover the demand for such information.

Waterproofing materials of a bituminous nature include bitumen and coal tar. Coal tar is the by-product of various industrial operations, such as the manufacture of illuminating gas, and the operation of coke ovens. It is not bitumen in the acceptation of the word as it was originally used by the Latin writer. Coal tar is a bituminous substance merely from its resemblance to bitumen. It is an extremely variable material, depending upon the character of the process by which it is produced and upon the uniformity with which the several processes are in themselves conducted. The one

great advantage is that it is an extremely adhesive material, but this is more than counterbalanced by its lack of uniformity, the readiness with which it changes its consistency on heating, and by the fact that it hardens and becomes very brittle with age, especially on exposure to the atmosphere.

Bitumen is a native material, that is to say, it is found in nature. It is a mixture of hydrocarbons and their derivatives and may be gaseous, liquid, a very viscous liquid, sometimes called a maltha, or a solid. The value of any bitumen or combination of bitumens for waterproofing purposes depends on the series of hydrocarbons and their derivatives, more particularly the sulphur compounds of which it is composed. The consistency of a bitumen, which is, of course, an important characteristic for use as a waterproofing material, is dependent on the relative proportions of the liquid and solid components of which it is composed, which can be regulated by the combination of various classes of materials. The softer hydrocarbons and their derivatives are soluble in naphtha and, as a class, have been denominated petrolenes, while those which are insoluble have been called asphaltenes. Whatever value a bitumen may have as a waterproofing material, is due to the character and relative proportions of these two classes of components. The asphaltenes in themselves have no binding power, but by solution in or mixture with petrolenes, which are adhesive, give them stability and body.

The value of bitumen as a waterproofing material will further depend upon the character of the petrolenes of which it is made up. If they are of a sticky nature, the material will be adhesive and cementitious, whereas if the petrolenes are merely oily and not sticky the material will be wanting in this direction. The asphaltenes impart cohesiveness as distinguished from adhesiveness and supply body or stability, as has been said, to the waterproofing material.

The heavy residuum left on the distillation of paraffine petroleums in the preparation of burning and lubricating oils, consists almost entirely of petrolenes which are oily and not sticky and adhesive. The same is true of any waterproofing preparations which are made of such residuum except where they are used to a moderate degree for softening a solid native bitumen. The petrolenes derived from asphalt and from asphaltic petrolenes, on the contrary, are sticky in character and, when reduced to a proper consistency as a component of waterproofing material, are particularly desirable when used to soften solid and hard bitumens, which possess great cohesiveness but are wanting in cementing properties. Alone, they are too susceptible to extremes of temperature to be used for this purpose. The relative proportion of sticky petrolenes and cohesive asphaltenes is one of the most important elements to be considered in regulating the consistency and character of waterproofing materials. However, even with the proper proportion of petrolenes

and asphaltenes, a bitumen may still be of little value as a waterproofing material if the petrolenes are oily. The characteristics of a waterproofing material may be summarized as follows:

1. *General Characteristics:* The series of hydrocarbons of which the bitumen is composed should be stated, for the purpose of comparing it with those in standard materials.

2. *Purity:* The amount of bitumen must be fixed, apart from the mineral or other matter with which it may be contaminated, to regulate the uniformity of the material.

3. *Adhesiveness:* This is arrived at from a determination of the specific gravity of the bitumen, its solubility in naphtha, the amount of paraffine scale which it contains, this being evidence of the fact that paraffine petroleums are present in the material or absent, and its ductility or extent to which a small test piece can be elongated under tension without fracture.

4. *Cohesiveness:* This is determined by the percentage of asphaltenes which the material contains, and by the residual coke remaining after ignition of the material in absence of air, which bears a close relation to the percentages of asphaltenes present.

5. *Consistency:* This is determined by the depth to which a weighted needle will penetrate into the material, under a definite weight, at a definite temperature, during a definite period of time.

6. *Viscosity:* This is determined by the rate at which the material will flow through an aperture of definite size, at a definite temperature, in a definite period of time.

7. *Capacity to Resist Temperature at Which It Becomes Sufficiently Liquid to Be Used in Actual Construction:* This is determined by the volatilization of the material when exposed for a definite length of time in a definite amount, to the high temperature at which the materials would be used.

8. *Safety:* This is determined by the temperature at which the vapor arising from the material at high temperatures, such as those used in manipulating it, will flash or take fire.

The blown oils and the combination of them with Gilsonite are all too viscous at high temperatures and all lack ductility which means that they are not adhesive, and are not self-healing when fractured. On the other hand, they are claimed to be more desirable because they harden less at low temperatures, but it is a question, in the opinion of the writer, whether this small advantage makes up for their deficiency in other directions. The petrolenes of which they are composed are of a very oily nature and the materials cannot be made to adhere as satisfactorily to metal or concrete as the products of the native solid bitumens, in which there is a fair balance of cohesive and adhesive properties. The latter are suitable both for mastic and for waterproofing coatings.

The fallibility of human nature will always prevent perfect de-

sign of engineering structures, and the use of an improper character of bituminous agent for waterproofing such structures will add to the imperfections of this design. Without resort to excessively fluid bituminous materials such as tar, or to the short blown-oil products, a cement of good balance, as far as cohesion and adhesion are concerned, should be employed if satisfactory results are to be obtained.

Mr. Finley: Mr. Richardson's discussion is particularly valuable. His long experience in the manufacture and use of asphaltic material gives the stamp of authority to anything he may say as to proper material to be used for waterproofing purposes. His remarks on fabrics and the proper saturation of them is entitled to careful consideration. My own experience bears out what he says regarding the necessity for careful saturation of burlaps. I am strongly of the opinion that coated burlaps are worse than useless.

I note Mr. Richardson's objections to the high melting point of my specifications. My object in specifying a high melting point was to avoid a material that would be too volatile. If the low melting point asphalts give a fair volatilization test, I would much prefer them to the others, as I appreciate the desirability of the self-healing qualities that Mr. Richardson mentions.

I think the Society is indebted to him for his very complete specification covering the various characteristics of a waterproofing asphalt, and I am satisfied that it will be of much help to engineers in selecting the proper grade of material for their work.

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings.

Regular Meeting, June 3, 1912.

A regular meeting of the Society (No. 787) was held Monday evening, June 3, 1912, President Armstrong presiding, with about 30 members and guests in attendance.

The meeting was called to order about 8:30 p. m. The Secretary read the minutes of the last regular meeting of the Society held May 6, which were approved.

The Secretary reported from the Board of Direction that the following had applied for membership:

David H. Dugan, Chillicothe, Ill.
James C. Loyth, Chicago.
George B. Mulloy, Chicago.
Robert S. Wallace, Chicago.
Allen T. Kirk, Joliet, Ill.
N. H. Jacobsen, Chicago, transfer.
George W. Phillips, Chicago.

Also that the following had been elected into membership:

James S. Pole, Chicago	Associate Member
Raymond D. Anderson, Fond du Lac, Wis	Member
Sidney T. Corey Chicago	Member
Wm. B. Poland, Manila, P. I	Member
R. P. V. Marquardsen, Chicago	Associate Member
James A. Dyer, Gillespie, Ill	Member
James R. Scott, Jr., Denver, Colo., transfer	Associate Member
L. W. Skov, Chicago	Associate Member
Benjamin Nelson, Chicago	Junior Member
Roy W. Flowers, Chicago	Associate Member
F. W. Kottke, Chicago, transfer to	Associate Member

There being no other business, the President introduced Prof. H. H. Stock, M. W. S. E. (University of Illinois), who presented his paper on "The Geology, Mining, and Preparation of Anthracite Coal." This was illustrated by a number of stereopticon views. Some little discussion followed.

The meeting adjourned about 9:45 p. m.

Extra Meeting, June 10, 1912.

An extra meeting (No. 788) under the care of the Bridge and Structural Section was held Wednesday evening, June 10, 1912. The meeting was called to order at 8:30 p. m., Mr. F. E. Davidson, chairman of the Section, presiding, and about 40 members and guests in attendance.

Mr. D. B. Luten, M. W. S. E., was introduced, who presented his paper on "Arch Design; Specialization and Patents," the paper being illustrated by many interesting lantern slide views. Discussion followed from Messrs. F. E. Davidson, R. G. Lawry, E. S. Nethercut, W. G. Langenheim, and the author.

Meeting adjourned at 9:30 p. m.

Extra Meeting, June 17, 1912.

An extra meeting (No. 789), in the interest of the Hydraulic, Sanitary, and Municipal Section, was held Monday evening, June 17, 1912. The meeting was called to order at 8:25 p. m., Mr. C. B. Burdick, chairman of the Section, presiding, and about 35 members and guests in attendance.

Prof. D. W. Mead, M. W. S. E., was introduced, and addressed the meeting on "The Cause of Floods and the Estimate of Their Intensity." A considerable number of lantern slide views were used to illustrate the address. Discussion followed from Messrs. J. G. Gabelman, B. J. Ashley, C. B. Stewart, J. W. Alvord, Jesse Lowe, Mr. Burdick, and replies and a closure from Prof. Mead.

Meeting adjourned about 11 p. m.

J. H. Warder, Secretary.

BOOK REVIEWS

The Books Reviewed Are in the Library of This Society.

Concrete Costs. Tables and Recommendations for Estimating the Time and Cost of Labor Operations in Concrete Construction and for Introducing Economical Methods of Management. By Frederick W. Taylor, M. E., Sc. D., and Sanford E. Thompson, S. B. John Wiley & Sons, New York. Chapman & Hall, Limited, London. 1912. Cloth; 8 by 5 in.; pp. 709, including index. Price $5.00 net.

This book is a convenient size, carefully indexed, and well printed. The object of the book, as stated by the authors, is that it may be found useful—First, to architects, engineers, and contractors in making accurate estimates of the cost of concrete work. Second, to contractors, superintendents, and foremen to help them to so lay out and plan their work that their materials will be economically handled and used, and that each workman will do more and better work. Third, to assist in the introduction of the principles of scientific management in the building trades.

The authors appreciate the difficulty of the introduction of scientific management in the building trades at this time, but they hope, as time goes on, that this feature will become the most important one of the book.

Another distinctive feature is the tables showing time required for men working at average speed and those working more rapidly, to perform all kinds of tasks. From these, other tables of costs for the tasks in question have been deduced, but, as the authors well say, time and costs so deduced are of little value without a knowledge of the best way to use them. In order to check these studies with actual practice, the methods and costs of leading contractors have been studied, and from these observations, methods of doing work are suggested, in the hope of standardizing these operations.

Many suggestions are given as to the layout of a plant, with costs for installation and of handling material.

There are chapters on approximate costs and short cuts in estimating both material and labor, also comparative costs of different designs in concrete buildings.

A chapter on "Task-Work in Construction" takes up the authors' well-known methods of scientific management and adapts them to building-construction. A chapter on "Proportioning Concrete" uses much material from the authors' book "Concrete, Plain and Reinforced." "Excavating and Crushing Stone for Concrete" is covered by a chapter of 40 pages. "Handling and Transporting Materials" is given 50 pages. Three chapters (170 pages) are devoted to hand mixing and machinery plants for mixing and conveying concrete, and labor costs for the same. "Forms and Arch Centers" cover 76 pages. "Tables of Concrete Volumes"; "Steel Areas and Quantities"; "Quantities of Lumber for Forms and Design"; "Times and Costs of Labor for Bending and Placing Steel and for Forms," cover 137 pages in six chapters. The final chapter (20 pages) is on "Estimates."

The care and labor expended in getting out this book is certainly very great, and many of the tables are especially useful. One's first thought is that the plan is entirely too ambitious for the present practice in concrete construction; but for those who have this idea there is an abundance of information, aside from the more scientific parts, and there is food for study throughout the book. The most important element will doubtless be the stimulation to study.

There are some things which experienced builders may disregard, but that argues nothing. In concrete work individuality and invention are still eagerly seeking their rewards, and effort to standardize methods will doubtless not receive the attention it deserves. Mistake, blunder, haste and laxity, on the one hand, and organizations and individuality on the other hand, are big human elements, the effect of which upon costs is extremely difficult to estimate, to say nothing about natural conditions of wind and weather. Fifteen or twenty jobs estimated to every contract, makes methods of estimating important. The book, if followed, will expedite matters in many ways.

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The reputation of the authors, together with the evident thought and care which they have given the book, make it of unusual value to those interested in this line of work. W. A. H.

Centrifugal Pumping Machinery. By C. G. De Laval. McGraw-Hill Book Co., New York. 1912. Cloth; 6 by 9 in.; pp. 184. Price, $3.00.

The intimate association of the author of this book with the Henry R. Worthington Company, leads one to expect valuable data, especially of an experimental character, covering many of the disputed points in centrifugal-pump design. The book describes in considerable detail the theory and design of centrifugal and turbine pumps, and gives applications to installations that have been made by the Henry R. Worthington Company, together with a general description and results of tests of many of the largest and most important installations that have been made by the Worthington company. Several methods of design are taken up: First, by using the ordinarily accepted formula expressing the head pumped against, as a function of the peripheral velocity, impeller vane angle at the circumference of the impeller, and hydraulic efficiency, as shown by previous test. Second, by expressing the relations between capacity, head, and speed, Q, n and h respectively, by an equation in the form

$$AQ^2-BQn-Cn^2=-2gh,$$

A, B and C being constants determined by previous tests.

For backward curved vanes, the form used is limited to that of a single center curve. The effects of various impeller vane angles at the circumference of the impeller, on the characteristic curve showing relations between capacity and power, capacity and head, and capacity and efficiency for constant speed, are stated briefly. The results of tests show that by careful designing the increase in power due to decrease in head can be kept within reasonable control for practically all conditions of service.

The form of the diffuser vanes used is that of an equi-angular spiral. The method of laying out this curve is described in considerable detail.

The book has many valuable suggestions and the results of tests of installations carried out show the possibilities of centrifugal pumping machinery for many engineering problems.

The nomenclature in the various parts of the book has not been made uniform so is somewhat confusing. The typography is excellent, but the editing has apparently been hurriedly done and in this respect the book could have been greatly improved.

Laboratory Problems in Physics to accompany Crew and Jones "Elements of Physics," by Franklin T. Jones and Robert R. Tatnall. Cloth; 5 by 7½ in., 81 pages. The Macmillan Co., New York, 1912. Price 50c.

This is a valuable book for use by students of physics, as it contains a series of clearly stated problems to be solved by the student, thus constituting an efficient review course. Emphasis is placed upon the problem to be solved, the fact or purpose to be learned rather than the method to be employed. By the aid of leading questions, the pupil's interest is aroused and his reasoning powers stimulated. Directions are provided and simple apparatus described for the work, and these exercises can be used in connection with most of the text-books on physics, but they are particularly applicable in connection with the text-book of Crew and Jones. The problems begin with the simple one of determining the value of π, the relation between the diameter and circumference of a circle. Other problems relate to the volume, and weight and density of a cylinder. The parallelogram of forces is well shown and explained, as is also the principle of moments and of parallel forces. The center of gravity receives due attention, and is followed by the subject of friction. The subject of surface tension (of liquids) is of interest of itself, and also the experiments to show its existence; capillarity naturally follows. The density of the air and its measurement receives due attention. Waves of water and the analogy of them to that of sound and their laws is also exhibited. Measurement of temperature is a

matter of great importance and receives due consideration. Other problems in this capital little book relate to electricity in one or another of its many and varied manifestations. The subject of light naturally follows, and the book concludes with a review of the metrical system of weights and measures.

The book is to be recommended to the instructor as well as the student of physics.

STANDARD FORMS OF FIELD NOTES FOR CIVIL ENGINEERS. By Charles C. Anthony, C. E. Cloth; 4¾ by 7 in., 55 pages, including 34 full page plates. Price $1.00. McGraw-Hill Book Co., New York, 1912.

This book is a very desirable one, particularly to young engineers engaged in survey work. Books have been published on surveying which give instructions on the handling of the instruments and perhaps state some of the problems to be met and their solution. These have a decided value to the student, but after they have been mastered and the young engineer is engaged in actual work, it is necessary for him to make records of his surveys, and though he may evolve some way of recording his observations, it frequently happens that the notes are not very intelligible to others who may have to make a plat of the work done. This book, through the medium of the plates, presents a rational and intelligent method of keeping the field notes, so that at any time they may be taken up by a stranger to the work and be readily understood.

The explanatory text is clear and concise, and if understandingly read and followed by the young engineer, his work will be of much greater value to his employer or the company engaging his services. The examples given, with sketches, cover such work as railroad station layouts, level surveys, stadia surveys, curve and spiral surveys, cross-section notes, park surveys, transit notes, hydrographic surveys, and soundings.

This book is highly commended to engineers and particularly to young men at the beginning of their professional career.

QUICK RULES FOR HEATING AND VENTILATING. Wm. J. Baldwin, Jr. Cloth; 4½ by 6 in., 24 pages. Published by the author. New York, 1912. Price $1.00.

The author is a son of William J. Baldwin, who wrote a valuable book on "Steam Heating for Buildings," which has passed through many editions. This little pocket-book gives, in condensed form for ready reference, rules for determining the sizes of heating apparatus to suit various conditions, boilers, radiators, steam piping, air ducts, etc., etc. The book is not a treatise on steam heating and should only be used by those who have had some experience in the subject, or at least have gained the fundamental principles by a study of, say, the father's work above referred to. But it does fill a place as containing data and rules for ready reference by the busy architect or engineer.

ELECTRICAL INJURIES, Their Causation, Prevention and Treatment. Designed for the use of Practical Electrical Men. Dr. Charles A. Lauffer, Medical Director, Relief Department, Westinghouse Electric and Manufacturing Co., East Pittsburg, Pa. 16 mo., 77 pages, cloth. John Wiley & Sons, New York. Price 50c.

This appears to be a valuable book, small enough to be easily carried in the pocket and thus ready for reference by the electrical worker. It is of particular value to those engaged about electric stations and transmission lines, where one is in some danger from burns, from flashes or arcs, or from coming in contact with charged machinery or circuits. The nature of the injuries are described and their proper treatment. The author shows, by illustration and text, how best to create artificial respiration, when necessary, after one has received an electrical shock of sufficint force to render the patient unconscious. It is the policy of the Westinghouse company to instruct their employees in theory and in practice of artificial respiration. By prompt action on the part of those so instructed many lives have been saved.

That company sends out instruction cards to power plants and central stations, with much good resulting. Much interest has been manifested by electrical men everywhere, in the way of precautions leading to prevention of such accidents and also to the resuscitation and care of those who have met with such an accident. The author describes the effect of flashes and the character of burns resulting therefrom; also the treatment of such burns. Valuable parts of this book are some chapters on "Minor Surgery and First Aid," "Infections," and "Effects of Occupation on Health." The book concludes with nearly 150 questions of review of the substance of this valuable little treatise, for which our thanks are due Dr. Lauffer, the author.

The Diary of a Round House Foreman. By T. S. Reilly. Cloth; 158 pages; 5 by 6¾ in. The Norman W. Henley Publishing Co., New York, 1912. Price, $1.00.

This book was originally presented to the public in a series of letters, written in diary form, published in the "Railway Review." These "stories" are pleasantly written and are interesting reading to men in the motive-power department of railway service. The book is recommended particularly to young men who have had more or less education in machine-shop work and mechanical engineering, as it shows how good, common "horse sense" is so necessary to success in a position of responsibility and particularly in dealing with locomotive engineers and firemen. Incidentally the writer mentions some of the problems that came to him for solution and how he obtained results. It is in this matter of administration that many good mechanics fail, and in which the author of the book succeeded, that conveys such good lessons to the young men in railroad work who are ambitious and desire to get ahead. In one chapter is reported a conversation between "the old man" and the young master mechanic, as he had then become. This contains some most excellent views on ethics and honesty in action as well as by word, between man (the boss) and those under him.

MEMBERSHIP.

Additions:

Anderson, Raymond D., Fond du Lac, Wis..........Member
Corey, Sidney T., Chicago..........................Member
Dyer, James A., Gillespie, Ill.........................Member
Flowers, Roy W., Chicago..........................Associate Member
Kottke, F. W., Chicago, transfer to................Associate Member
Marquardsen, R. P. V., Chicago....................Associate Member
Nelson, Benjamin, Chicago..........................Junior
Poland, Wm. B., Manila, P. I.......................Member
Pole, James S., Chicago............................Associate Member
Scott, James R., Jr., transfer to....................Associate Member
Skov, L. W., Chicago...............................Associate Member

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ARCH DESIGN; SPECIALIZATION AND PATENTS

DANIEL B. LUTEN, M. W. S. E.

Presented June 10, 1912, before the Bridge and Structural Section.

Twenty years ago there was hardly a concrete arch in the United States; ten years later there were less than a hundred; today there are upwards of ten thousand. This suddenly accelerated growth is due to a realization that the concrete arch fulfills most of the requirements of an ideal highway bridge. Arches of material other than concrete, such as stone, brick, and steel, have been lacking in some important attribute so that no sufficient number have been erected in a limited period to enable any engineer to specialize exclusively in arch design in those materials.

REQUIREMENTS OF THE IDEAL HIGHWAY BRIDGE.

The ideal highway bridge must include among its qualifications the following:

1. Permanence, eliminating repairs and inspection.
2. Artistic appearance to harmonize with its surroundings.
3. Strength increasing with time and traffic.
4. Safety, meaning not merely security but slow failure in case of defects.
5. Stable on insufficient foundations and under extreme flood conditions.
6. Of effective waterway providing maximum discharge.
7. Efficient and economical in use of materials.
8. Employing home labor and materials.
9. Providing a roadway continuous over bridge and approaches.
10. Easily widened to provide for increasing traffic.
11. Easily modified in design to conform to improvement in surroundings.
12. Simplicity in design and erection.

Eighty-foot arch, Ripley, N. Y., of plain design, in harmony with its rugged surroundings of rocks, trees, and hills.

HOW THE REINFORCED CONCRETE ARCH COMPLIES WITH THESE REQUIREMENTS.

1. Permanence.

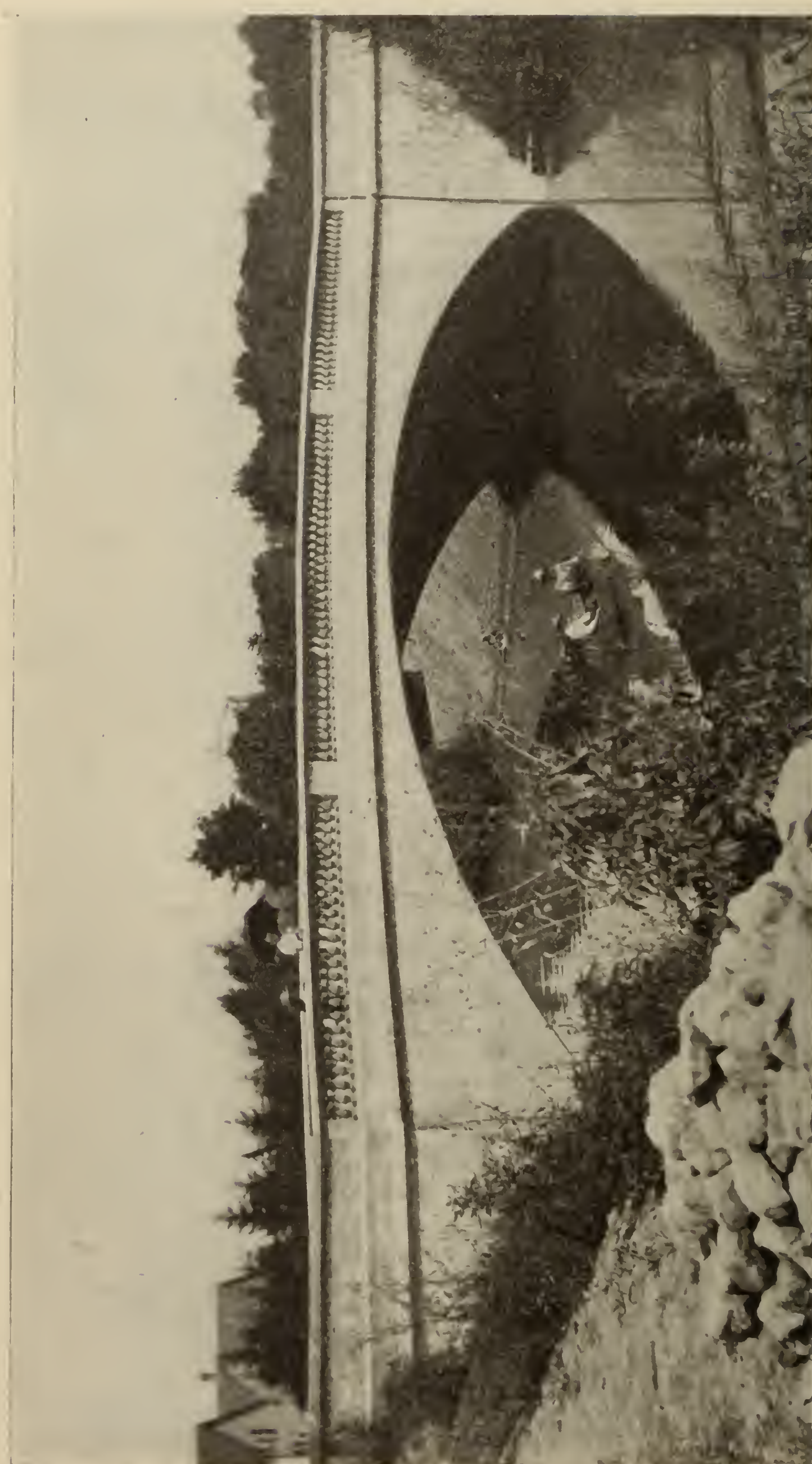
An arch of concrete reinforced with embedded steel has all the permanence of stone; in fact it is more permanent than the usual building stones, and has none of the limitations of steel, such as corrosion and crystallization; for concrete is but slightly affected by the elements, and the embedded steel is protected from rust and vibration. No painting or repairs are ordinarily required, and inspection is superfluous.

2. Artistic Appearance.

A properly-designed reinforced-concrete arch will be in equilibrium under the fixed load. Reinforcement will be required in the arch ring to resist moving load stresses only, and the moving loads are small in comparison with the fixed load. Such a structure, therefore, displays its material in an efficient form, and because of its useful application presents a beautiful appearance. Everyone knows that concrete is a material strong in compression. Its use in the arch without ornamentation, consequently appeals to the eye. This is wholly apart from the relation of the bridge to its surroundings, in which harmony must be secured ordinarily by ornamentation of spandrels and railings. There is no harmony, for example, in adopting a segmental curve or parabolic arc for an earth-filled arch merely because it carries railway loading, when such curves are not the curves of equilibrium, for the loading.

Since the concrete arch is of pleasing form when properly designed, all that is necessary to make it harmonize with its surroundings is to limit the design to dignified details for rugged surroundings, and to embellish it with ornamentation for cultivated surroundings. No other bridge structure harmonizes so readily with its surroundings, no matter what they may be. The mechanical lines of the truss and girder appeal to the eye of the trained engineer and are usually more pleasing on the drafting table and in the blue print than the arch. But the actual structure after erection and in perspective is nearly always a disappointment both to the engineer and the layman when compared with a well-designed arch.

For spans of less than 100 ft., dignity of design can usually be best secured for an arch bridge *of moderate rise* by the use of the earth-filled type with solid spandrels. But a semi-circular arch can hardly be made to present a satisfactory appearance with solid spandrels, unless the depth of load over the crown be proportional to the rise, not an economical arrangement. For spans greater than 100 ft., especially with great rise, the open-spandrel construction is usually to be preferred, and this accords fairly well with economy in this country, at the present cost for labor and materials. In Europe, where labor is relatively cheaper, it may be desirable from the standpoint of economy to use open spandrels on spans as



Sixty-five-foot arch, Horlick Park, Racine, Wis., illustrating beauty of camber in copings and railings.

short as 60 ft. or 75 ft. A hollow spandrel behind a solid spandrel wall is rarely desirable, for the curve is then not in harmony with its loading except for very flattened spans. In a concrete girder it is extremely difficult to show by external treatment the presence of the steel that resists one-half of the stresses. Appropriate paneling will accomplish it in part, but in any event the reinforced-concrete girder must always leave an impression of weakness that cannot be satisfied by any external treatment.

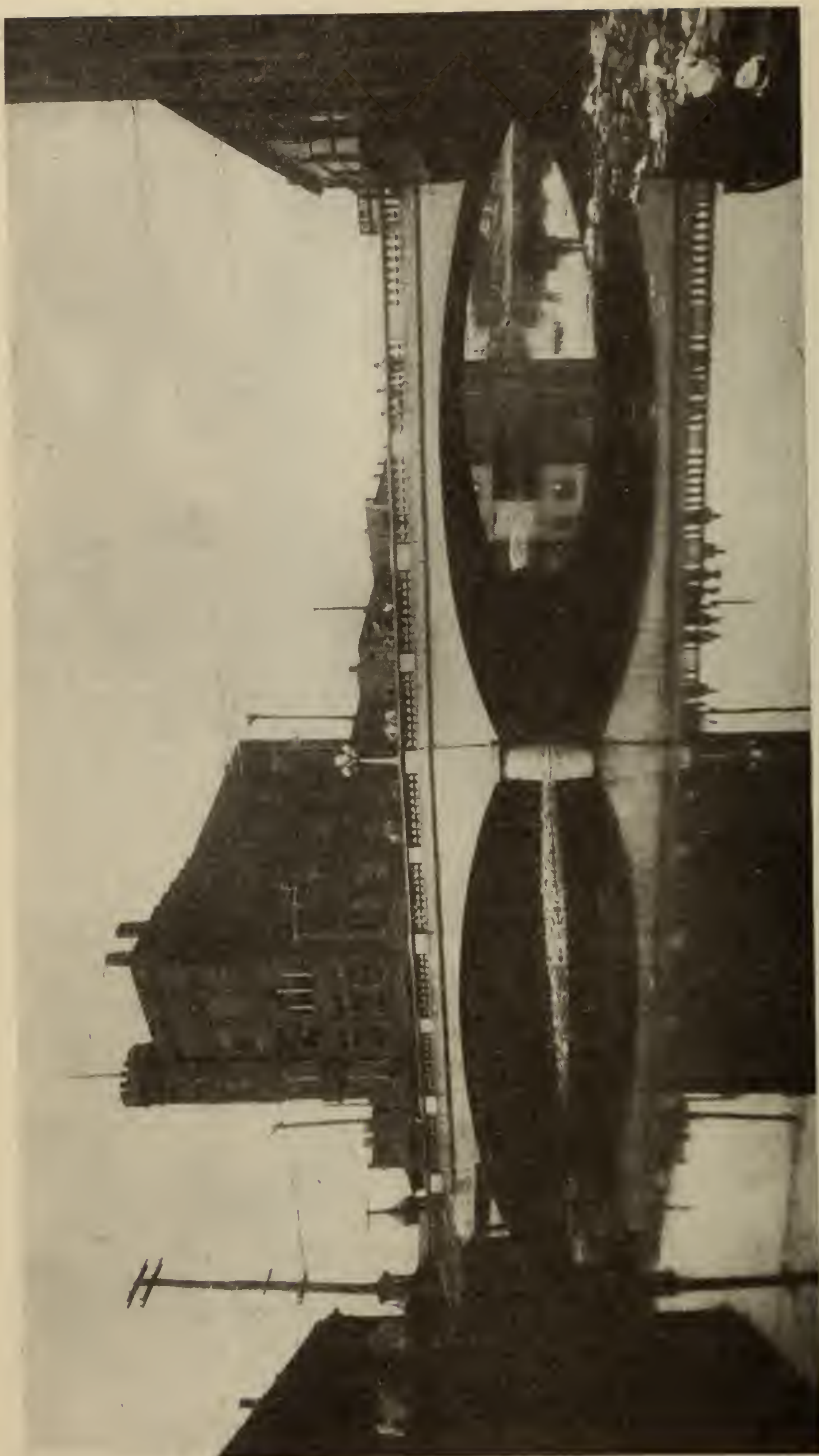
An arch bridge, whether in single span or in series of arches, presents the best appearance when cambered in a vertical parabolic curve having a rise of about 1/150 the entire length of the bridge, but not ordinarily to exceed 3 ft. This ornamental camber in the arch bridge also provides for surface drainage of the roadway which may be discharged through the crowns of the arches, if not objectionable below.

3. Increasing Strength.

Timber, steel, and even stone deteriorate as they grow older. Concrete grows stronger with age. The increase may amount to 50% in the year following the first thirty days. Since traffic on most of our highways is constantly increasing in weight, such an increase in strength tends to keep pace with the growth of traffic. A bridge that decreases in strength must be built excessively heavy, for the day soon comes when its decreasing strength meets the increasing traffic, and collapse results. The bridge that increases in strength with age may be designed for efficiency. Hence the light efficient design is to be commended in such a structure, whereas it receives merited condemnation in steel or wood.

The concrete arch, since it depends for its strength principally upon the compressive strength of the concrete, does increase in strength as the concrete gains in strength, and it is the only type of bridge that possesses this property. The concrete girder, designed for equal efficiency of steel and concrete, cannot gain any advantage from the increasing strength of the concrete except by overstressing the steel. Designing the girder with excessive allowable stress for concrete in compression enables the girder to grow in strength with age, for a limited time only, but at the risk of a collapse in the early period of its existence. This is taking the chance that no full load comes over the structure in its first year. As the concrete of the arch hardens the elastic arch becomes less flexible and will distort less under a concentrated load. Hence the tension in its embedded steel will be reduced as the structure grows older. And since the concrete grows harder and better able to resist higher compressive stresses, while the tension in the steel is at the same time reduced, the structure as a whole grows stronger as its age increases.

An earth-covered arch also increases considerably in strength but in an unknown ratio, by reason of the compacting of the earth



Twin spans of seventy-five feet each, Newcastle, Pa., of ornamental design in railing and lamp-posts of reinforced concrete.

fill over the arch and behind the abutments. Many earth-covered arches have been erected with light abutments reinforced with ties from abutment to abutment to resist the thrust, from which the ties have been removed after two or three years to permit the deepening of the channel, and with no resultant yielding of the abutments.

4. Safety.

A bridge made of any structural material may be designed to safely support its load by a proper distribution of the material. To make a bridge secure, therefore, whatever the material or type, is simply a matter of design. But no matter how well planned, a bridge may be defective in erection. In such a case a bridge that fails slowly and with abundant warning is superior to one that collapses suddenly. A structure in which tension forces are isolated in separate members, as in a truss, fails suddenly when any member gives way. A girder of steel or concrete in which the dead load forces are concentrated in extreme regions, as top and bottom flange, will follow the same behavior in a less marked degree. A concrete arch with open spandrels supported by separate arch ribs will collapse suddenly in limited regions supported by a defective rib. But a concrete arch covered with earth filling and stiffened with spandrel walls not only fails slowly but gives abundant warning of overstress. Failure in such a structure is almost always by yielding of abutments or piers which move slowly. There are many instances of reinforced concrete arches which have settled continuously for months, developing cracks but without failure. In one instance the crown settlement in an 80 ft. span amounted to several inches before it was stopped by a support under the crown.

Reinforced concrete has one marked advantage over most other materials, in that it may indicate conditions of maximum allowable tension in its embedded steel before actual danger exists. This advantage rests in the fact that the coefficient of elasticity of the concrete and of the embedded steel do not bear the same ratio as their allowable stresses. When the embedded steel is stressed to 5000 lb. per sq. in., invisible cracks occur in the surrounding concrete. At 10,000 to 15,000 lb. per sq. in., these cracks become visible. At 20,000 lb. per sq. in., they frequently become objectionable. Herein lies one of the objections to the use of hard steel of high elastic limit, for its coefficient of elasticity has not been increased with its tensile strength, and consequently it cannot be subjected to greater stresses per square inch than the usual allowable 16,000 lb., without danger of unsightly cracks.

If it were desirable to use steel to reinforce concrete in compression, this different ratio for the coefficients of elasticity might be considered a serious drawback. But with concrete at $7.00 per yd., and steel at 2c per lb., the cost of steel is forty times that of concrete, while its compressive strength is but thirty-two times as great, assuming safe allowable stresses of 500 lb. per sq. in. for con-

crete and 16,000 lb. for steel. So that even with a proper relation of elasticity, the use of steel in compression would rarely be economical. And with steel assumed to have a modulus of elasticity of 30,000,000 and concrete 3,000,000, the ratio is ten, so that steel embedded in concrete may not be stressed higher than 5,000 lb. per sq. in. for 500 lb. in contiguous concrete. When steel is used in tension it has every advantage over concrete in economy, since concrete sustains safely but 50 lb. per sq. in. in tension. This lack of harmony in the elasticities of steel and concrete is, therefore, in reality a highly desirable feature, tending to prevent the skimping of the steel through use of excessive allowable stresses. The use of transverse ribs on the steel for the avowed purpose of distributing such cracks is equivalent to sitting on the safety valve. If such ribs really do distribute such cracks their field of usefulness is limited to high carbon steel.

In arch design, where the stresses in the arch are magnified by the behavior of the spandrel walls, cracking of the concrete serves the purpose of an extensometer to detect excessive stresses. If an arch is designed too flat at the crown, cracks will appear in the spandrel near the ends of the span. If too flat at the haunches, cracks will appear in the coping over the crown or through the arch ring at the haunches directly under the spandrel only, and not extending far into the soffit of the arch. The tensile stress in the arch itself is rarely sufficient to show cracks actually penetrating the arch ring. Small cracks, particularly in the spandrels, are no indications of failure, being merely the magnified effects of moments in the arch ring, but a *properly designed and erected* arch will be free from such cracks, if provided with expansion joints in the spandrels above each springing.

5. Stability.

The arch imposes a heavier load upon its foundations than any other type of bridge. But since there is no limit to the expansion possible in footings, the intensity of pressure may be made the same as for any other structure by proper distribution, so that the heavier loading of the arch is objectionable only as affecting its comparative cost. It proves a decided advantage, in fact, when the effects of moving loads on the structure are considered. The heaviest locomotive loading may increase the foundation pressures under a steel trestle of 100 ft. span, several hundred per cent, whereas the corresponding increase under an earth-covered arch of the same span rarely exceeds 20%. The stresses in the latter structure itself are not seriously affected by a considerable increase in the moving load.

Steel and wooden bridges have one great advantage over concrete bridges in stability, in that they can sustain unequal settlements without serious damage. Concrete bridges are not seriously affected by uniform settlement of one or both abutments. But un-

Twin spans of sixty feet each, near Lima, Ohio, with rise of six feet and crown of twenty inches.

fortunately, settlement of an abutment is very rarely uniform. Unless founded on rock, the materials underlying any abutment of 18 ft. or 20 ft. length in the average stream are of varying character, whether clay, sand, gravel, or piling. Settlement, if it occurs, due of course to excessive intensity of pressure, will always be greater at one point than another. If an abutment settled uniformly it would not crack. But how many abutments that have settled are free from cracks?

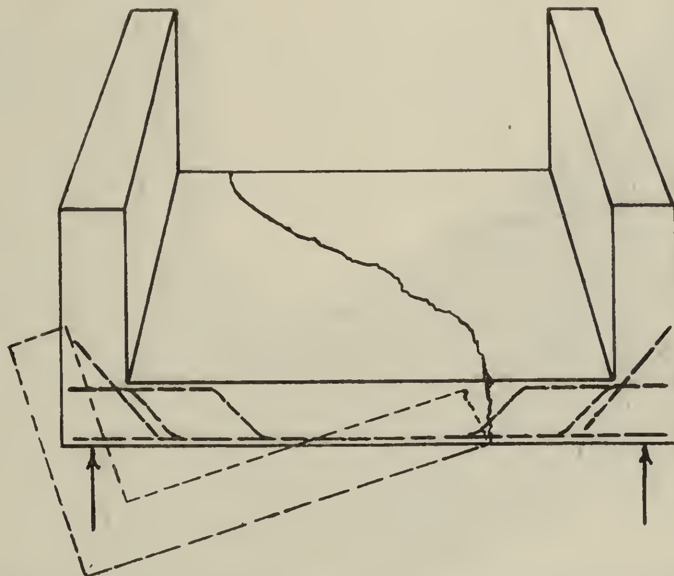
Many authorities have reasoned hastily, from a comparison of steel arches and girders, that a concrete arch is more seriously affected by settlements than a concrete girder. They have overlooked a serious difference, which is that the concrete girder has a solid concrete floor slab incapable of sustaining material distortion, while the steel girder has floor beams whose connections will permit considerable distortion without failure. The concrete girder as usually designed consists of a solid floor slab carried upon reinforced-concrete girders forming a deck, or hanging between the reinforced-concrete girders and forming the through girder type. These girders transmit the loads to the abutments or piers at isolated bridge seats. If a bridge seat yields under its load, it is not thereby relieved in any degree of its loading, for the floor system is wholly incapable of supporting the girder. The behavior of such a girder bridge may be likened to that of a square floor slab supported at four corners on columns; now assume one column removed and imagine the result! If the bridge be a through girder, the collapse of the girders will follow the shattering of the floor slab. Hence the through girder of concrete is a dangerous type of bridge for doubtful foundations.

The concrete arch, even of the earth-covered type, is adjustable to such unequal settlement, for by cracking transversely in lines diagonal to each other, unequal settlement may occur to a considerable extent without total destruction. Such cracking of the arch ring will be invisible for small settlements, and collapse will not necessarily follow the cracking, because the material will be largely in compression and may behave like the voussoirs of a stone arch. The strength of the structure may be impaired, depending upon the degree of the settlement, but complete destruction will not necessary result immediately, as in the concrete girder, whose end is nearly always sudden.

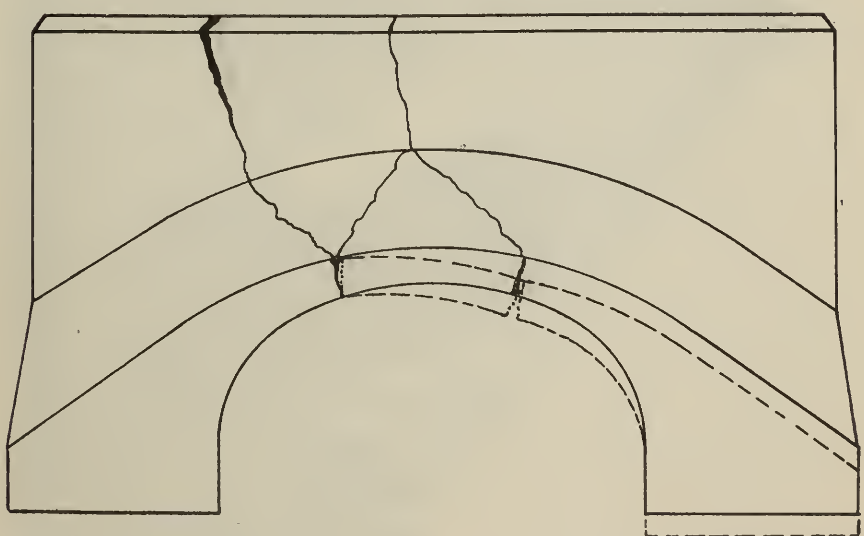
Cracks in the spandrel walls are usually the worst results of unequal settlement in arches; and they are merely symptoms indicating the condition of the structure. When final stability is reached, the cracks may be sealed, or, if unsightly, the spandrel walls may even be removed and rebuilt with every prospect of remaining free from cracks thereafter. So that slight unequal settlements in concrete arches are not necessarily serious matters. The earth-covered concrete arch, therefore, is better adapted to doubtful foundations

than the concrete girder, and is a much more suitable structure when rock foundations are not to be found.

The open-spandrel arch with solid floor slab supported on columns is more nearly comparable with the deck girder in effects of unequal settlement. For, while the arch rib may sustain distor-



Illustrating settlement of one corner of through concrete girder. Result, diagonal crack leaving each half unstable.



Illustrating settlement of one corner of solid arch ring, the structure nevertheless remaining stable.

tion without serious unjury, the resultant settlement in the solid floor slab will prove a source of danger.

The introduction of one, two, or three hinges in a concrete arch is utterly useless as a provision for *unequal* settlement. If the arch be a solid rib, hinges which are parallel to each other cannot relieve

Heavy mass effective in sustaining moving loads and in resisting floods and ice.

unequal settlement. If it be of separate ribs hinged separately at the crown or at the springings, or both, the presence of the hinges will permit unequal settlement of the ribs and their supporting footings; but these ribs must support columns which carry a solid concrete floor slab. Unequal settlement of footings and ribs will necessarily cause unequal settlement of the floor slab, a structural member that is incapable of sustaining it. Hinges, therefore, are entirely inadequate to alleviate the stresses arising from unequal settlements. Nor are they at all essential in providing for changes of temperature, as will be shown later. The most useful purpose of a hinge in an arch is to locate the thrust line and reduce a complex analysis to simplicity in the office, by the use of a complicated and expensive device in actual construction. The use of a hinge in such an arch by an expert designer is rarely justified. It is an admission of inability to solve the engineering problems of analysis of the proper arch ring and the substitution therefor of a clumsy field expedient. Its main purpose is to avoid the difficulties of the elastic theory. It is on a par with the use of a parabolic rib under an earth fill, the parabolic rib being of simple mathematical solution, while the desirable arch ring for such loading is extremely complex in analysis.

The concrete arch with its great mass is not readily moved by floods nor ice jams. It is consequently a desirable type of structure for a low-level bridge subject to complete submergence. In such cases its roadway and approaches should be paved to prevent scour. A wooden block pavement, so desirable for steel bridges because of its light weight, is rather undesirable on a concrete bridge because of the possibility of its floating away. The wide abutments required by a concrete arch to resist its horizontal thrust add to its stability in flood, for such an abutment may often be undermined for a considerable area at the stream face without injury, since the maximum pressure is at the back. Arch piers are much more frequently undermined than arch abutments, while girder abutments are more frequently destroyed by undermining than the piers, because the earth pressure behind the girder abutments makes the stream face the weak point for attack. The horizontal thrust of an arch, often cited as objectionable, is, like heavy loading, merely a matter of proportioning, since the abutments can readily be designed to resist it. It becomes a matter for criticism only when the cost of such provision becomes excessive.

6. Waterway.

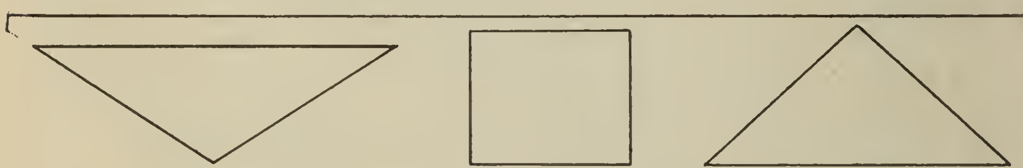
For the purpose of comparison, consider the three fundamental types of waterway possible, *V*-shaped, rectangular, and inverted *V*, all of equal area. The *V* opening is the type desirable for sewers where a small flow of water must produce a deep swift current to carry solids along a uniform channel. It is not suitable for an opening for a bridge, since it must dam back the water before ca-

pacity can be secured. It requires the longest span for a given area of waterway.

The inverted *V* opening provides the greatest span at the lowest level, hence it will provide the greatest discharge at low levels and with least damming effect. It requires a long span, but permits the use of the arch instead of the girder.

The rectangular opening is intermediate to the other two in effective discharge, and has the advantage of shorter span, limited, however, to the girder type. It appeals to most designers because the entire superstructure can be made to clear the former high-water records. But this apparent advantage rests wholly on the assumption that future high-water levels will conform to that record. It frequently happens that former high records are broken. When the water actually does reach the lower edge of a girder or truss bridge, trouble is almost sure to result from lodging debris, ice, or the lifting effect of the water. At such times a little additional head room at the crown of an arch is greatly to be desired even though it has been secured by the sacrifice of some waterway at the haunches.

For the same waterway area, therefore, the arch type of open-



Comparison of three types of waterways.

ing has a considerable advantage over the girder and sewer forms. But for a given span and a fixed water level, this advantage no longer obtains.

Comparing bridges of equal spans, the arch of the same span and height of opening reduces the waterway of the circumscribing rectangle about 20%. In a stream flowing three miles per hour, the increased head required to compensate for this reduction in area would be about 3 in., neglecting friction, ice, debris, etc. The difference in head would be given by the formula:

$$(v^2-v_1^2) = 2g(h-h_1). \text{ Or, } h-h_1 = \frac{v^2-v_1^2}{64} = \frac{(v+v_1)(v-v_1)}{64}$$

For a velocity of three miles per hour, or 5 ft. per second, a 20% restriction in area would require a 25% increase in velocity. Substituting 6¼ ft. for v and 5 ft. for v_1, the difference in head is given as approximately one-quarter of a foot. Assuming that friction loss may amount to one-third, a decrease of 20% in waterway area still means a damming up of but 4 in. above normal in a flooded stream. Because of camber and higher opening at the crown, the reduction in area is usually not more than 10%. Again, to permit high water

Twenty-two-foot deck girders of concrete, illustrating constriction in waterway area.

to approach more closely than 3 ft. or 4 ft. from the lower chord of a truss bridge is to court danger in a stream that carries debris in times of flood; while the concrete arch will serve satisfactorily under similar conditions up to almost complete submergence of the crown.

Concrete girder bridges require greater depth of floor system than steel girders or trusses. And the concrete deck girder, used for spans exceeding 25 ft., in which the roadway slab is supported on girders, cannot give even the equivalent waterway area of the arch of the same span. The only way in which the concrete girder bridge can compete with the arch in waterway area is by raising the girders and hanging the roadway slab between them, but which must be limited to a narrow roadway. A submerged waterway, as sometimes obtained by excavating under the bridge only, and below low water, is not effective except for discharge under head, and even then it is of but slight value except for very short spans. Sim-

Three arches of span seventy-four feet each on Meridian Street, Indianapolis, in flood of March, 1905, that destroyed every truss bridge on the stream. No lodging of debris and but four inches of head.

ilarly, water backed up to a fixed level under a bridge limits its capacity almost entirely to the area above that level.

Short-span slab bridges on pier or column supports may be made to show a larger waterway area at low cost by ignoring the obstructive effect of the supports. But for streams that carry debris they are suitable only for railroads having an organized track force available to prevent lodgment of debris in time of flood. The use of such trestles in short spans of 16 ft. or 20 ft. in flood streams is inspired by the limitations of reinforced concrete in the hands of its designer rather than by actual merit. Where is the engineer, for example, that has ever recommended a steel trestle of 16 ft. or 20 ft. spans for such locations? In designing in steel he uses the long-span truss or girder, although the economy of short-span column and beam construction would be quite as marked in steel as in re-

inforced concrete. A series of spans of less than 30 ft. each will not pass debris satisfactorily such as will continue to run in nearly all of our streams for centuries to come, and 50 ft. to 60 ft. spans as a minimum are much to be preferred. A span of 60 ft. is almost essential to permit the passage of other bridges that may wash out farther up stream.

The danger of obstructing streams with short-span trestles is brought home to the erection foreman of any bridge that must be supported during erection on falsework bents of 16 ft. span, the usual practice. After the removal of this falsework the bridge

Steel bridge lodged against twenty-foot arch in flood that completely submerged the arch.

of 60 ft. to 100 ft. spans may safely be left to the attack of any flood; but while the short-span falsework is in place, floods are continually dreaded, and all hands are needed to clear away the debris when floods occur.

7. Efficiency.

Concrete is a material high in compression values and low in tension and shear. If an arch be designed as a linear arch for the fixed load, it will have no tension, and no shear whatever except in

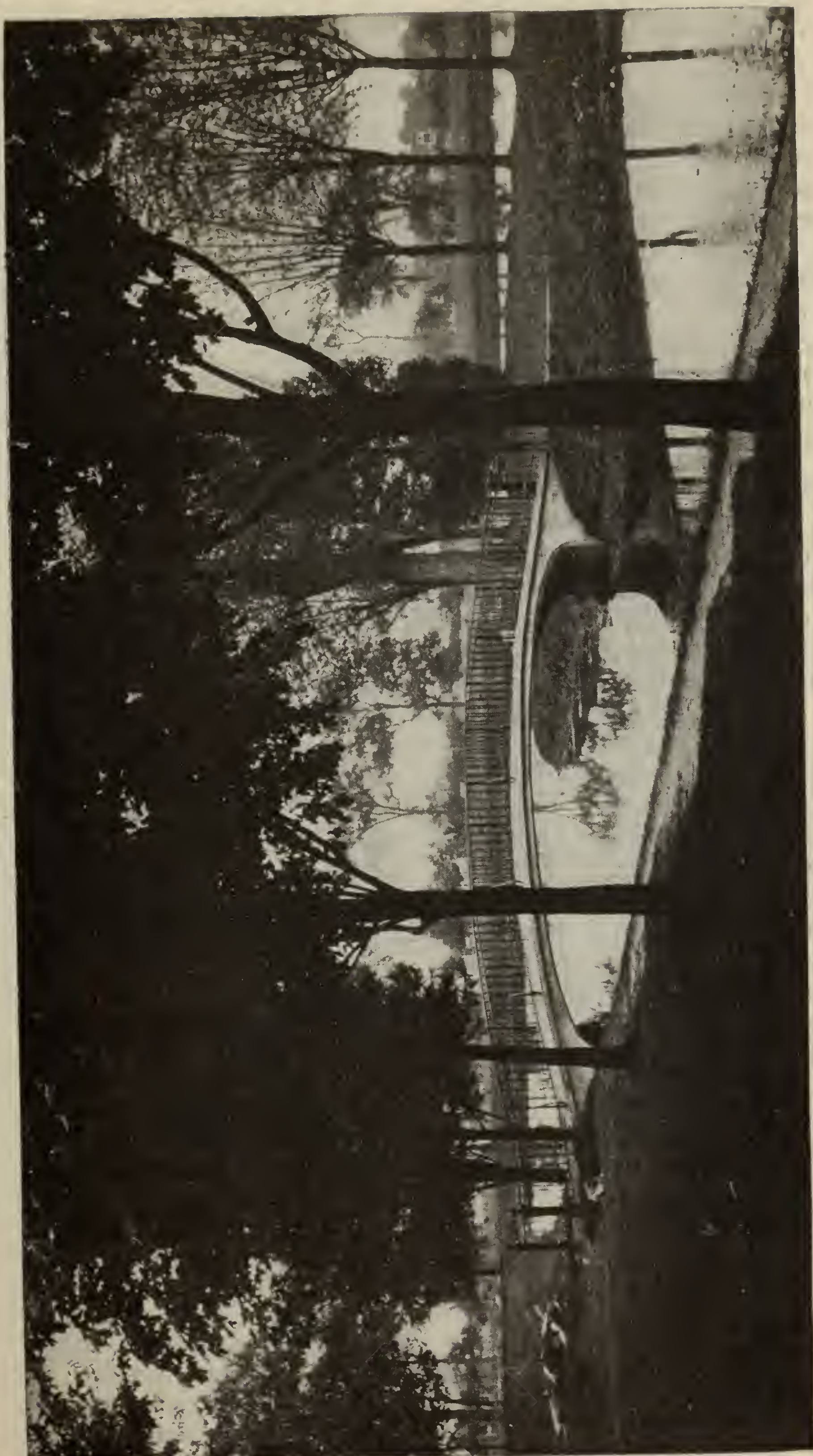
very slight degree for temperature changes and moving loads. The stress in such an arch approximates very nearly uniform compression throughout. Consequently, for a location where a rock foundation is exposed at the surface, no structure of concrete can compete in cost with the arch. But when footings must be expanded to provide for soft foundations or insufficient backing, the advantage is less marked. Nevertheless, the reinforced concrete arch is usually of lower first cost than the concrete girder for the same requirements, in spans exceeding 20 ft. or 30 ft. It will also compete with steel girders and trusses having permanent floor and substructure.

The concrete girder is remarkably inefficient in its use of materials, although the deficiency is compensated to some extent by greater simplicity in form erection and less excavation. In the concrete girder, that portion of the concrete below the neutral axis of the slab and girder serves only to protect the embedded steel and is otherwise at all times worse than useless dead weight. Above the neutral axis the concrete is stressed to maximum at the top in the middle of the span only, falling to zero at all other extremes, thus averaging but little more than one-eighth of the entire superstructure doing full duty. The test girder of 40 ft. span by 16 ft. roadway at the Joliet State Prison, was commented upon at the Kansas City convention of the National Association of Cement Users, as being a most remarkable example of efficiency in a through girder concrete bridge, since it had sustained a uniformly distributed load of 640 tons. To sustain the same load *under the same conditions* on a 40 ft. linear arch, would have necessituated a crown thickness of only 1½ in., provided so thin a section would sustain the usual ultimate stresses.

8. Home Labor and Materials.

In but few and widely scattered communities are materials directly available for building bridges, except of wood and concrete. Even for wooden bridges of long span, suitable timber must now be imported for most northern counties. For such bridges and for steel, almost all the expenditure for superstructure is, therefore, sent out of the county, and usually out of the state. For concrete arches, the cement amounting to 10% of the cost, and the steel amounting to 5%, together with 5% for superintendence, are all that are necessarily foreign in expenditure, a total of about one-fifth. The concrete girder exports 10% for cement, 25% for steel, and 5% for superintendence, or about twice as much as the arch. Unless the profit on an arch exceeds 20% therefore, it is better policy for a community to let contracts for arches even to outside contractors than to award contracts for girders to home talent, all other advantages being assumed equal. And a similar comparison for steel bridges might exclude them altogether.

As the reinforced arch is increased in span, the percentage of



Thirty-foot span, Columbian Park, Lafayette, Indiana; efficient use of materials.

steel required actually decreases, which is quite the reverse in the case of all other bridges. This is due to the fact that the steel reinforcement, being required principally for live-load stresses, is proportionately less in the long heavy span than in the short lighter span, because of the lesser relative effect of a concentrated load on the longer, heavier bridge. Any rule which requires a certain percentage of steel to the cross section, may apply to the girder, but is based on an erroneous conception of arch action, when applied to the crown of an arch. In many long-span concrete arches, say of 200 ft. or over, there is no advantage in any arch reinforcement whatever. And if used indiscriminately, in compression for instance without suitable restraining stirrups, it may actually weaken the structure. Embedded steel in compression should be restrained at intervals not exceeding ten or fifteen diameters of the compressed steel member.

9. Continuous Roadway.

A bridge that requires an earth covering has an advantage in that the earth roadway, or gravel, macadam or brick pavement may be extended directly across the structure with no break whatever in its continuity. It is objectionable to build with a level floor of concrete, or any other material that does not have provision for carrying the same materials used in surfacing the highway leading to the bridge. For a change in paving material usually means a chuck-hole where the harder pavement joins the softer. And even an earth covering over a concrete deck is apt to show such depressions after wet weather, unless the earth or gravel covering is more than 12 in. thick. The covering over an arch reduces in depth gradually to a desirable minimum of 8 in. to 12 in., and there is, therefore, no formation of chuck-holes if earth covering is used, nor any difference between the earth covering of the bridge and the earth foundations of the road or street itself. Any kind of pavement or surface can thus be obtained over the arch with the same construction as the roadway approaches.

There should be no guard rail between the walk and roadway on such a structure, for the pedestrian has more opportunity for escape on the bridge than on a city street. Refuge bays are often favored in the expectation that they will afford a view of the bridge; on the contrary, they obstruct such view except when located at the extreme ends of the structure.

Temporary floors, such as plank or *unprotected* concrete, render the structure so temporary in character as to be hardly worthy of consideration except in communities short of funds. In order to replace such floors with more permanent construction, the entire destruction of the superstructure is usually imperative; for little saving is made in first cost by such temporary floors, except in the reduced weight of the superstructure. To lay a reinforced concrete floor as part of the structural members, but to serve later

Gravelled roadway over three-span arch bridge at Plainfield, Indiana.

Twin spans of seventy-five feet each at Newcastle, Pa., showing walks, brick pavement, and double track street railway.

Bridge over Maumee River at Waterville, Ohio; ballast roadbed on earth fill.

as the foundation for a pavement, is also poor practice, unless the reinforced floor is protected absolutely from wear while awaiting its covering of pavement. Inspection of highway and city bridges is too lax to permit of taking chances on such construction for the limited saving that will be realized.

10. Widened Roadway.

The standard width of highway bridges in the middle western states is now 16 ft.; in many southern states 12 ft. is customary; in eastern states 24 ft. has become quite usual. As a community grows older, it frequently becomes necessary to widen bridges to provide for increasing traffic that could not have been foreseen, or that would have required excessive cost in the original construction. It sometimes occurs that a bridge is erected with a 16 ft. roadway, and that later the coming of an interurban railway builds up the community about the bridge, necessitating a structure of much wider roadway. Through bridges of truss or girder type cannot ordinarily be widened without scrapping the superstructure. If the supporting steel trusses or girders were originally heavy enough to carry the additional load, which, of course, is rarely the case, they can be moved apart and supplied with heavier floor beams. But the through girder of concrete cannot be widened and since its only advantage is large waterway, it is limited by the necessity for a shallow floor system, to a roadway width of 16 ft. or 18 ft. Hence it can hardly be considered a permanent bridge in any sense except in a locality that is at a standstill in population or value. The extended use of such a bridge by any community is a standing advertisement of lack of progress in population, wealth and road improvement, for since it has not even the excuse of low cost to commend it, and *is* intended to be a permanent bridge, it signifies lack of faith in any future growth.

Deck bridges and arches can be widened at any time without loss of any of the original investment except moving the railing and possibly burying the spandrel walls in the added fill.

11. Modified Design.

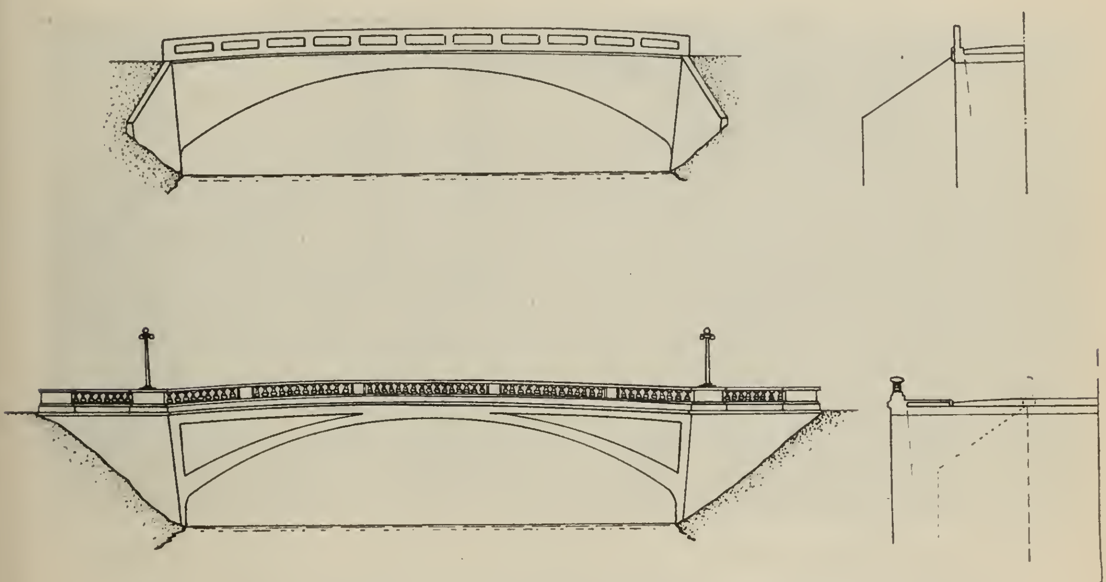
The necessity for a wider roadway on any bridge usually accompanies an increase in valuation of property together with a demand for handsomer improvements. A concrete arch bridge may be erected with a narrow roadway, plain paneled railing, wings, and spade finish, to secure efficiency with low cost. As the community grows richer a wider roadway, say of 24 ft., may be demanded, and at the same time opportunity is thus afforded to hide completely the original structure, and to face both the up-stream and down-stream sides of the old bridge with a new structure conforming to the old curve of the arch, but having new spandrels. The latter may now be chiseled or bush hammered with slightly contrasting

panels and surmounted by a handsome railing of posts, spindles and caps, wired for electric lights on reinforced concrete posts, and with spandrels extended back of the abutments instead of the less sightly wings. All of this with no appreciable waste of material by reason of the earlier, cheaper design.

Through bridges, whether of steel trusses or concrete girders, do not admit of any such treatment except by the addition of a *complete* roadway at each side of the old structure, the roadway then being obstructed by the unsightly girders or trusses rising above the roadway between them.

12. Simplicity in Design and Erection.

In the matter of analysis, the reinforced-concrete arch is far from being ideal and is perhaps as difficult an engineering structure



Cheap design modified into ornate design with wider roadway.

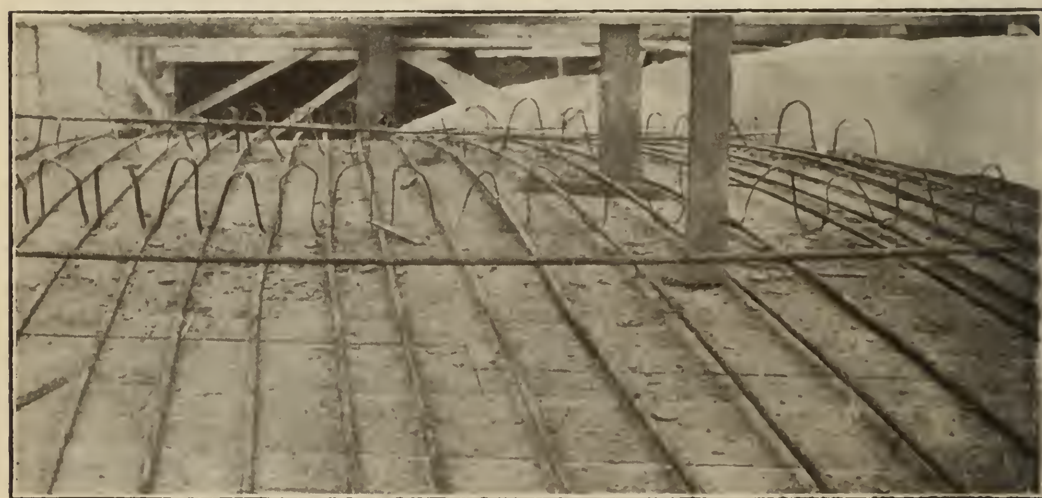
to deal with as has been devised. To properly determine the maximum and minimum stresses in a single-span arch will ordinarily require one expert five or six days of continuous computations.

In erection, on the contrary, simplicity lies with the arch. The erection of centers and placing of reinforcement requires only the ordinary skill of an average carpenter. The finishing of the concrete requires skilled men, but a larger proportion of the concrete arch is erected with unskilled labor, than in the case of any other type of bridge. Except for the foreman and two or three skilled assistants, labor is usually secured from the immediate vicinity of the bridge. Truss bridges require skilled labor in nearly all parts of fabrication and erection. A concrete girder is more simple in form erection than the arch but much more complicated in

the placing of the steel reinforcement, which is not only four or five times as heavy as that for the same span arch but is also much more complex in details of fabrication.

From almost every standpoint, therefore, *except simplicity in analysis,* the concrete arch excels in qualities that go to make an ideal highway bridge. And the one seriously objectionable feature of intricate analysis can be removed by standardization of arch plans; for when an arch of given span and rise has once been analyzed and properly proportioned, the same design will, of course, satisfy the same requirements for another similar location.

The preparation of the plans for an arch of given span is a small matter when the sizes of details are known. Complete drawings for an 80 ft. arch can be prepared by a single draftsman in half a day. In two days' time the entire drawing necessary for a



Arch reinforcement in place for sixty-five foot arch, showing simplicity of reinforcement.

$50,000 concrete arch bridge can be laid out; but if every span must be separately analyzed for details, a month is too short a time. Once a complete set of standard designs has been developed by expert analysis, it serves as the basis for any number of other plans that can be prepared *without* detailed analysis. These standard designs may be supplemented by tables and formulæ to interpolate between various spans and rises. Thus the difficulties of the elastic theory for arches may be eliminated and arch design reduced to a basis of commercial usefulness, so that plans may be supplied promptly and at low cost just as for other manufactured articles.

Designs and sections taken from technical journals have not in the past, at least, been typical of good practice in arch design, for the structures that have been given publicity have ordinarily

been the first efforts of inexperienced designers. An engineer is always anxious to "write up" his first 50 ft. arch; but later structures of the same span, although they will represent better practice resulting from his increased experience, have lost their novelty and no longer make attractive "stories." Nor are the technical journals anxious to publish descriptions of arches which they deem to have become standardized by extended repetition; reduction in thickness of 25% in an arch ring is not a sufficient novelty to place before their readers. Consequently, technical journals, and text-book compilations from such journals, cannot be relied upon to supply a guide to the best practice. The elastic theory is our best guide in spite of its numerous drawbacks. But it is not a toy to be placed in the hands of a novice. It requires expert interpretation in every step taken.

LIMITATIONS OF THE ELASTIC THEORY.

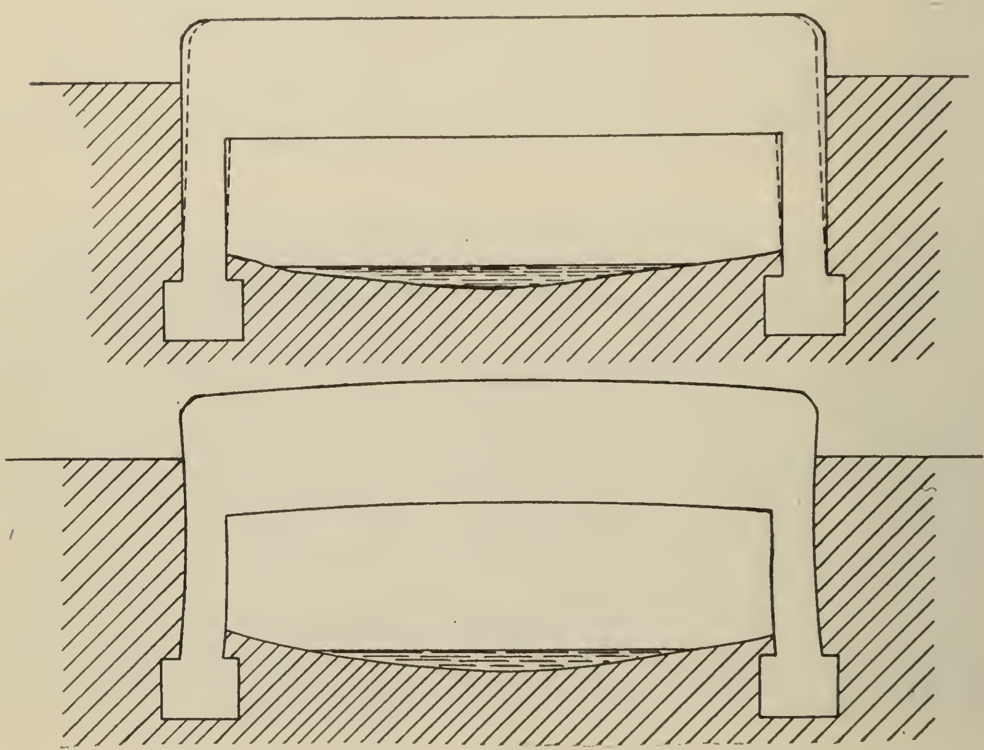
The elastic theory as applied to reinforced-concrete arches is still in its elementary stages of development. No method has yet been devised of satisfactorily analyzing an arch of concrete in which any material tension occurs. No satisfactory method of determining the tensile stress in the steel is known. No text-book shows any proper application for moving load analysis for arches on piers. A serious objection to the elastic theory is that as ordinarily applied it shows excessive stresses at the springings for temperature changes. These extreme stresses do not actually occur, and some designers have endeavored to offset them by permitting higher allowable stresses for temperature variations or by assuming a low range of temperature. Just why a higher allowable stress should be permissible for temperature variations than for a fixed load, is difficult to explain. Common sense would indicate, regardless of experiments, that a range of ± 40 deg. would be the least that could be expected in this latitude.

Even so good an authority as Professor Howe says in his text-book on "Symmetrical Masonry Arches," page 81:

> "As a large number of railway bridges have been built upon practically the dimensions we assumed, and no indications of failure having been found, we must conclude that the range of temperature change ($\pm 40°$) assumed in this example is very much too great. Furthermore, it requires a drop in temperature of only *four* degrees to completely balance the compression produced by the dead load in the upper fibers at the support. Without question, then, our assumptions about the effect of temperature changes are not correct. Until we know more about the subject it is useless to make calculations according to the ordinary assumptions."

Yet the range of temperature undoubtedly *is* as great as that assumed, and this has been confirmed by recent experiments. A large part of the difficulty consists in the limited length of arch ring usually assumed to be elastic.

The temperature stresses in an arch are not as extreme as those in the bedstead girder type of concrete bridge, in which the span is supported on legs of reinforced concrete with no provision for expansion and contraction. For spans exceeding 30 ft., the temperature stresses in such a structure may become very severe, but are often overlooked because the girder and abutment are analyzed separately, whereas the elastic theory for arches neces-



Bedstead concrete girder without provision for expansion. Exaggerated view of behavior. Critical point of high stresses where girders join supporting legs.

sarily involves the relation of the abutment to the arch. The detrimental effects of temperature in a bedstead concrete bridge are magnified, too, by the earth pressure back of the supports.

COMPARISON OF RESULTS BY DIFFERENT ANALYSTS.

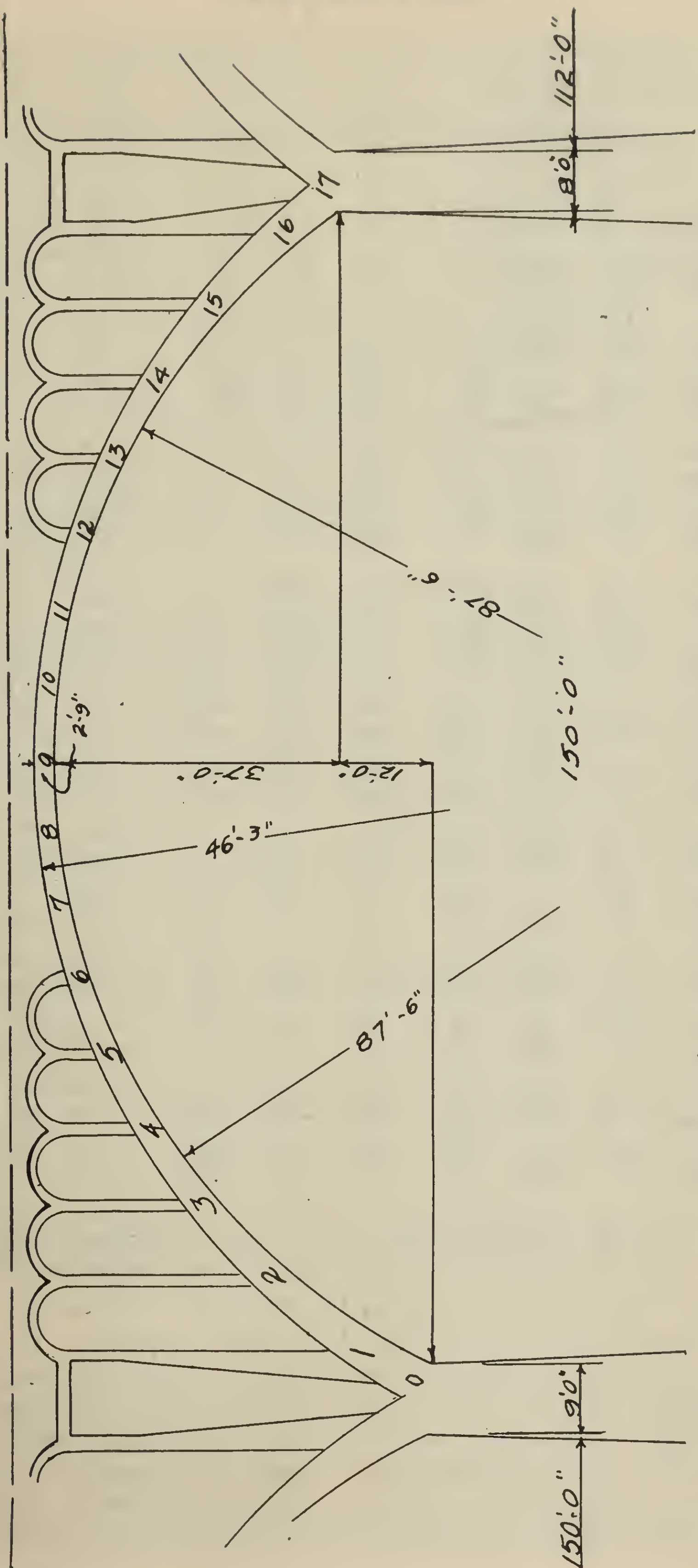
In illustration of the danger of intrusting a novice with the application of the elastic theory, the following comparison of results may be of interest. A city of nearly 500,000 population proposed to erect a concrete bridge and had designs made that adhered closely to steel precedents. In fact, all of the engineers connected with the project had acquired their training in steel design. The writer proposed to the city officials that bids should be considered also upon his competing plans. This proposed compe-

tition was opposed by the engineering department but was nevertheless viewed with favor by the officials having supervision. A design was, therefore, submitted by the writer to the supervising officials who, without suspecting all the latent possibilities in consulting biased experts, turned the plans over to the engineering department for approval. They were, of course, promptly condemned, on numerous grounds, one of which was that stresses in the steel reinforcement would exceed 77,000 lb. per sq. in. of tension for dead load. In reporting them unsatisfactory, the city engineer presented a table of stresses and stated that he had determined the stresses by the methods outlined in Balet's "Analysis of the Elastic Arch" and Turneaure and Maurer's "Reinforced Concrete,"—the latest standard works. The writer thereupon submitted the same plans to Professor Parker, Assistant to Dean Turneaure, Madison, Wisconsin, and to Jos. W. Balet, of New York City, and secured from each his stresses for the same span under the same assumptions as laid down by the city engineer. Fixed-load stresses alone are considered here, for the reason that live-load stresses may be determined under numerous varied assumptions, not only as to distribution but as to application of the elastic theory, and it was apparent from the report that the city engineer had not made suitable assumptions for live-load analysis. The complexity of such anaylsis is another obstacle; Mr. Balet reported that he had spent sixteen days on the fixed-load analysis alone.

The arch that was analyzed consisted of a 150 ft. unsymmetrical span supported at each end upon a pier, and loaded with short spandrel arches whose supporting walls extended completely across the arch ring. The arch was, therefore, under vertical loads with no earth pressures to be considered and, under the assumptions made by the city engineer, was quite free from any ambiguities as to fixed loading. Each of the two experts was asked to determine the stresses at extrados and at intrados at sixteen points that had been fixed by the city engineer. The results are tabulated in three sets of parallel columns, under dead-load stresses and rise and fall of temperature. Rib shortening is included in the dead-load stresses.

Mr. Balet overlooked part of his instructions and analyzed for ± 30 degrees temperature instead of $+20$ and -40 degrees assumed by the city engineer. The table shows no harmony whatever in the results, except that Mr. Balet's stresses for 30 degrees fall in temperature correspond substantially with Professor Parker's results for a drop of 40 degrees. Professor Parker shows no tension for dead-load stress, and no compression exceeding 400 lb. per sq. in. Mr. Balet shows 365 lb. per sq. in. *compression* at the identical point where the city engineer reported 77,000 lb. *tension* in the steel! It is apparent from a study of the columns that no average of the three nor of any two could give hopeful results, yet each of these analysts insists that his own work is correct. As a matter of fact, none of the stresses as determined is correct for

Twelve spans of seventy-five to ninety feet each, across Maumee River at Waterville, Ohio.



Unsymmetrical arch of 150-foot span. Analyzed by elastic theory.

MAXIMUM STRESSES IN ARCH RING IN POUNDS PER SQUARE INCH.

	DEAD LOAD STRESSES.			TEMPERATURE RISE.			TEMPERATURE FALL.		
	Parker.	City.	Balet.	Parker. 20°	City. 20°	Balet. 30°	Parker. 40°	City. 40°	Balet. 30°
1-Extrados	396	−114	529	44	22	104	−88	−43	−96
Intrados	6	554	160	−42	−22	−100	84	45	93
2-Extrados	237	−268	366	36	19	88	−72	−35	−94
Intrados	163	706	22	−34	−17	−84	68	37	90
3-Extrados	168	−223	266	26	12	51	−52	−24	−66
Intrados	206	655	130	−23	−10	−48	46	20	61
4-Extrados	199	−75	231	12	4	37	−24	−7	−30
Intrados	210	507	180	−9	−2	−30	18	3	21
5-Extrados	246	101	234	−3	−5	5	6	10	−5
Intrados	171	313	188	7	7	3	−14	−14	−3
6-Extrados	290	234	211	−18	−13	−32	36	25	31
Intrados	134	200	229	23	15	42	−46	−31	−39
7-Extrados	320	284	182	−30	−21	−40	60	41	57
Intrados	108	154	269	34	23	68	−64	−47	−67
8-Extrados	285	289	118	−37	−24	−63	74	47	66
Intrados	147	143	336	42	26	71	−84	−53	−66
9-Extrados	287	225	52	−39	−24	−53	78	48	68
Intrados	148	211	402	44	26	63	−88	−54	−78
10-Extrados	313	147	61	−33	−19	−35	66	36	56
Intrados	120	291	393	38	21	45	−76	−42	−46
11-Extrados	330	143	119	−21	−11	3	42	21	−2
Intrados	99	301	327	26	13	7	−52	−27	−8
12-Extrados	280	92	144	−6	−1	30	12	1	−21
Intrados	143	350	292	10	3	−22	−20	−5	21
13-Extrados	209	53	101	11	10	57	−22	−20	−42
Intrados	207	369	329	−7	−8	−51	14	16	50
14-Extrados	158	−50	85	27	19	67	−54	−38	−69
Intrados	254	474	329	−24	−17	−61	48	34	63
15-Extrados	149	−115	118	39	26	85	−78	−53	−86
Intrados	256	545	282	−36	−26	−79	72	51	82
16-Extrados	250	−111	257	48	31	102	−96	−62	−104
Intrados	147	546	117	−46	−31	−98	92	60	102

150 FT. UNSYMMETRICAL ARCH, VERTICAL FIXED LOADS ONLY.
COMPARISON OF STRESSES DETERMINED BY THREE DIFFERENT EXPERTS.

this design, although those given by Professor Parker are, in the writer's opinion, correct for the limitations imposed. Given the elastic theory in the hands of one lacking in practical experience in its application, there is no telling what harm may be done. The above analysis was made for the simplest possible conditions of vertical load only, and with concentrated loads neglected, yet but one of the three supposed experts can have produced reliable results; the other two varying in some instances several hundred per cent.

Experts are not agreed as to how concentrated loads are to be applied to an arch bridge. The loads are usually assumed as uniformly distributed over a given number of longitudinal sections of unit width. This method of distribution may often prove far in excess of actual loading for a solid arch ring, for in such a structure properly bound together by reinforcement, there can be no failure by slicing out a ring of unit width, say 1 ft. The piers or abutments will overturn or yield, not in isolated longitudinal sections, but as a whole. The arch ring will collapse as a whole and not by sections. A fairer distribution assumes the stresses at a maximum under the load, decreasing to zero at the limits of the arch width, and this is still on the side of safety. In proportioning piers between arches, this assumption becomes vital for the excessive pier restricts the waterway at the same time that it consumes too much material. Hence, in a pier analysis particularly the concentrated load should be distributed in some manner over the entire pier length.

STANDARD DESIGNS.

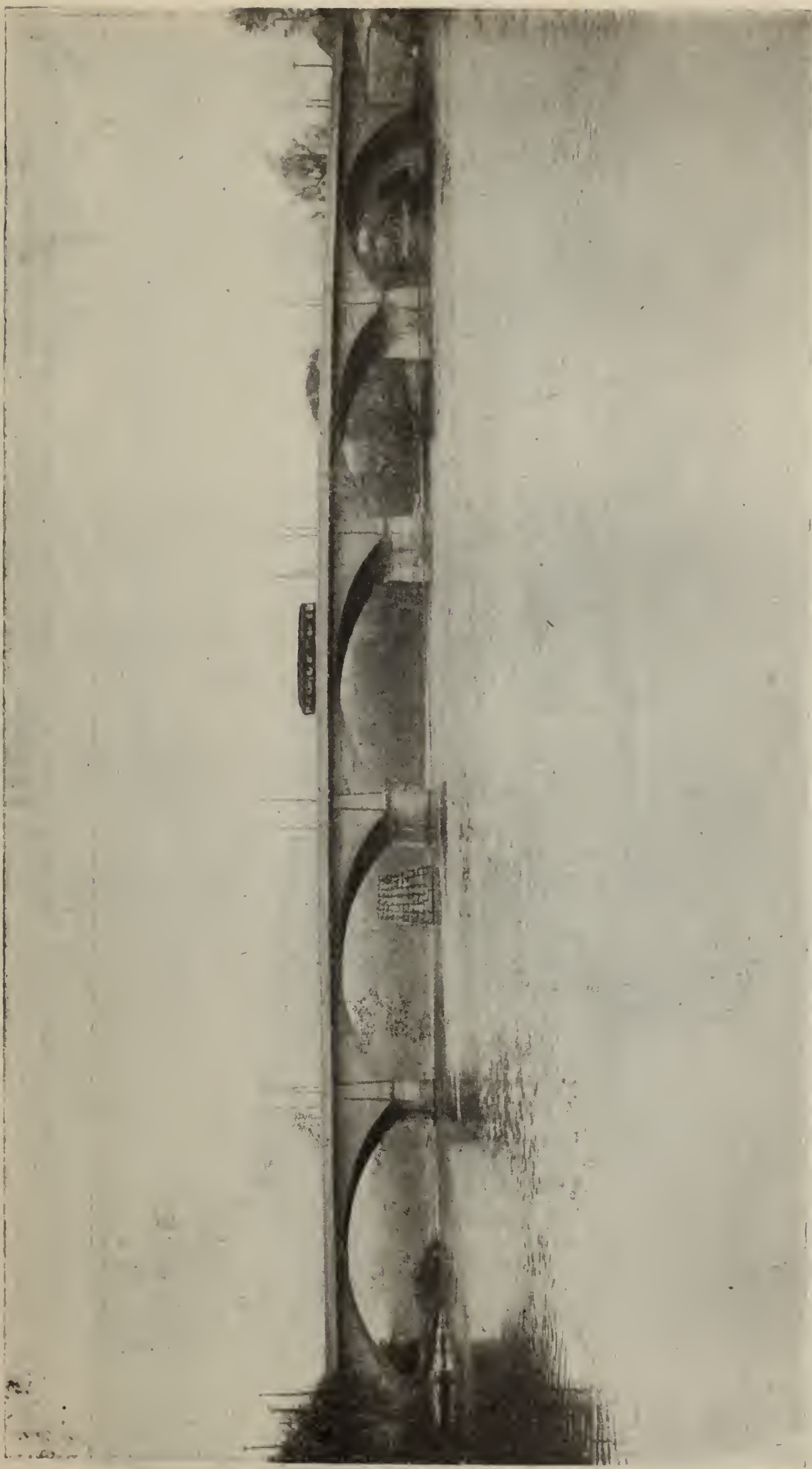
Under conditions of intricate and doubtful analysis, it is not a simple matter to establish standards by which designs can be made promptly and reasonably when required. But by combining with such methods of analysis a close and critical examination of actual structures, erected in accordance with such analyses, standards *can* be developed, although by a slow and expensive process. And in the early stages of such development, design and erection must go hand in hand. Once the field has been fairly well covered by such standards, the actual construction may be abandoned to advantage for engineering specialization.

Such standard designs cannot be copyrighted, and since they must be filed openly for public competitions they cannot be kept secret. There is nothing, therefore, to prevent anyone else from appropriating results earned at great labor and expense. It is a common occurrence to find an engineer designing an arch by formulæ or sections developed at great cost and at the same time to be refused by that engineer an opportunity to secure any benefits whatever from the supposedly open competition. The engineer's objections to submitted plans and to the employment of an expert in the simple problem of letting a concrete bridge, are often of more weight to him than any arguments for fair play or wider competition.

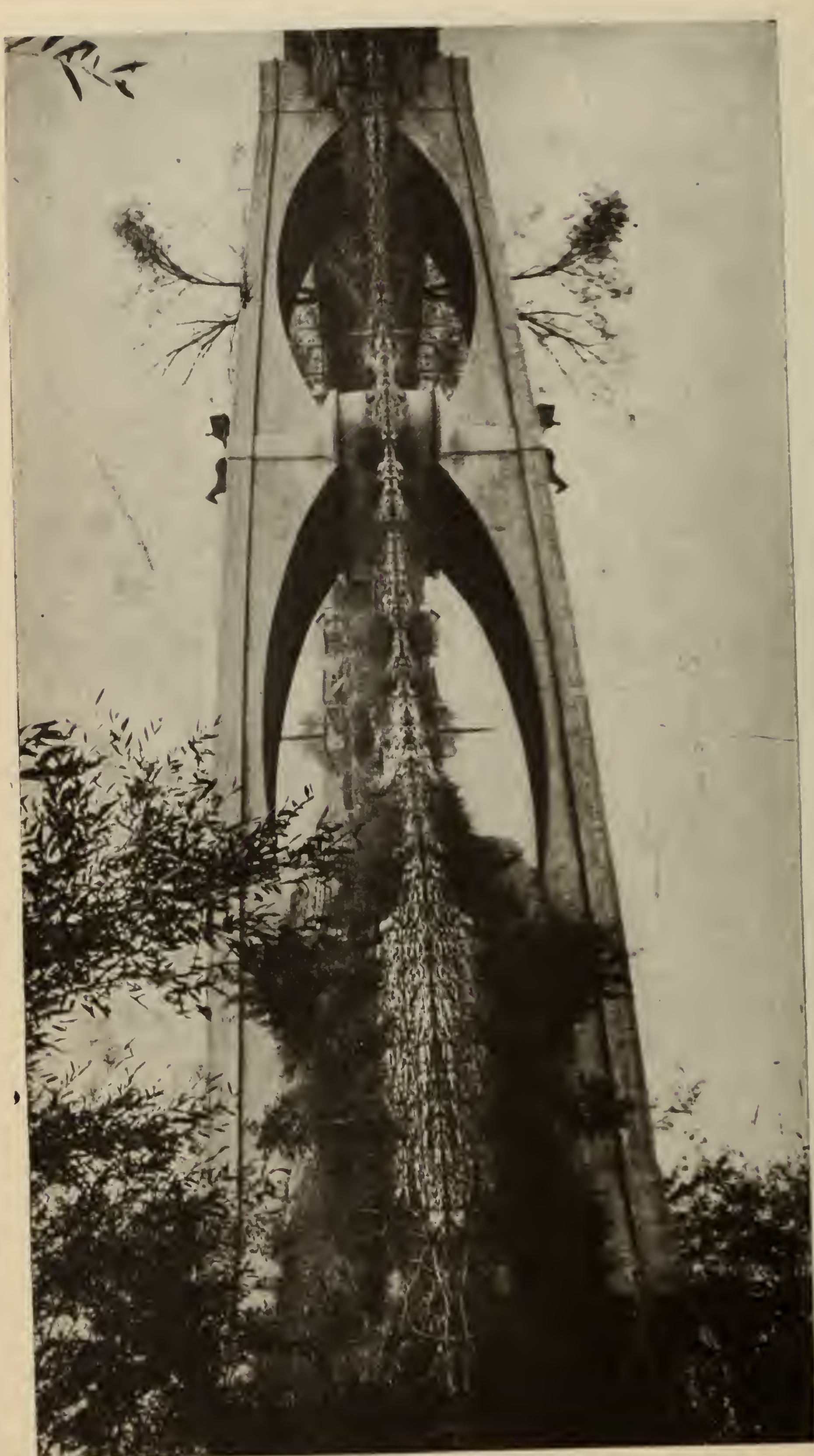
PATENT PROTECTION.

The only remedy in such cases is patent protection; not patents on the standard designs, which, of course, are not patentable, but on every possible improvement in design or erection that tends to make the structure more efficient. By securing patent protection on cost-saving improvements, the specialist may secure partial protection for his specialty to enable him to devote the capital and en-

Fifty-five-foot span balanced by forty-five-foot span on light piers but two feet nine inches thick.



Five spans of eighty-eight to one hundred feet each, Nashua, N. H., with piers but five feet thick and thirty feet from base to springing.



Twin spans of eighty feet each, Linn Grove, Indiana, plain, solid earth filled arches in perfect harmony with the surroundings.

ergy necessary to reduce the difficulties of the elastic theory to a basis of practical helpfulness in arch design.

A patent is a contract between the United States Government and the inventor, whereby the inventor makes a full and complete disclosure of his improvement in return for seventeen years' exclusive enjoyment of its benefits. By making a complete disclosure of his improvement, he enriches science, art, or manufacture. He does not rob anyone of any right or privilege enjoyed prior to the invention, for in just so far as he reserves to himself anything that previously belonged to the public, to just that extent is his patent invalid. It must add something to the public good and must not subtract from it, if it is to stand in court.

A patent is infringed by anyone, without exception, who makes, uses, or sells the patented device without a license from the patentee. An engineer may infringe by designing and supervising it. If the patent is valid, a federal court will issue an injunction to prevent repetition, upon proof of such infringement, past or prospective. An infringer has practically but one escape from an injunction with royalty and costs, and that is to prove that the patentee was not the original inventor in this country. Unless one can establish such prior invention and use, beyond any question of doubt, he cannot safely infringe the patent. Prior use alone in a foreign country does not invalidate a patent granted by the United States Government.

Patent protection does not retard an industry, but promotes it. So far as the writer has known, no patent on reinforced concrete has ever been used to limit engineering production. Their sole use has been to retain for the patentee competitive rights that otherwise would have been abridged. Patent litigation is profitable to no one, but it is forced upon one who sees his improvements appropriated at the same time that he is refused an opportunity to compete. Patents on reinforced concrete have not retarded its development, but they may seem to do so, to those who have come into the industry at a late hour and find part of it occupied. He who protests is like the squatter who appropriates the land that another has earned by his industry. A patent is not so monopolistic as ownership of land. Criticism of patents and opposition to court decisions is usually most strenuous by those who least understand the fundamental principles and laws underlying patent protection.

Engineers frequently object to paying royalty, feeling perhaps that it has not been earned, but the way to determine whether a patent earns the royalty demanded is to subject it to competition. In arch design for example, wholly aside from patent protection and the difficulties of the elastic theory, arches can be designed that do not infringe patents. This is particularly true of concrete arches, and more so than of any other type of concrete bridge, for a concrete girder bridge cannot be designed without infringing some patents. Hinged arches may be designed also to eliminate the difficulties of

the elastic theory. The results may be comparatively crude in the light of recent improvements, but if those improvements are patented the owner is entitled to part, at least, of the saving that they have occasioned.

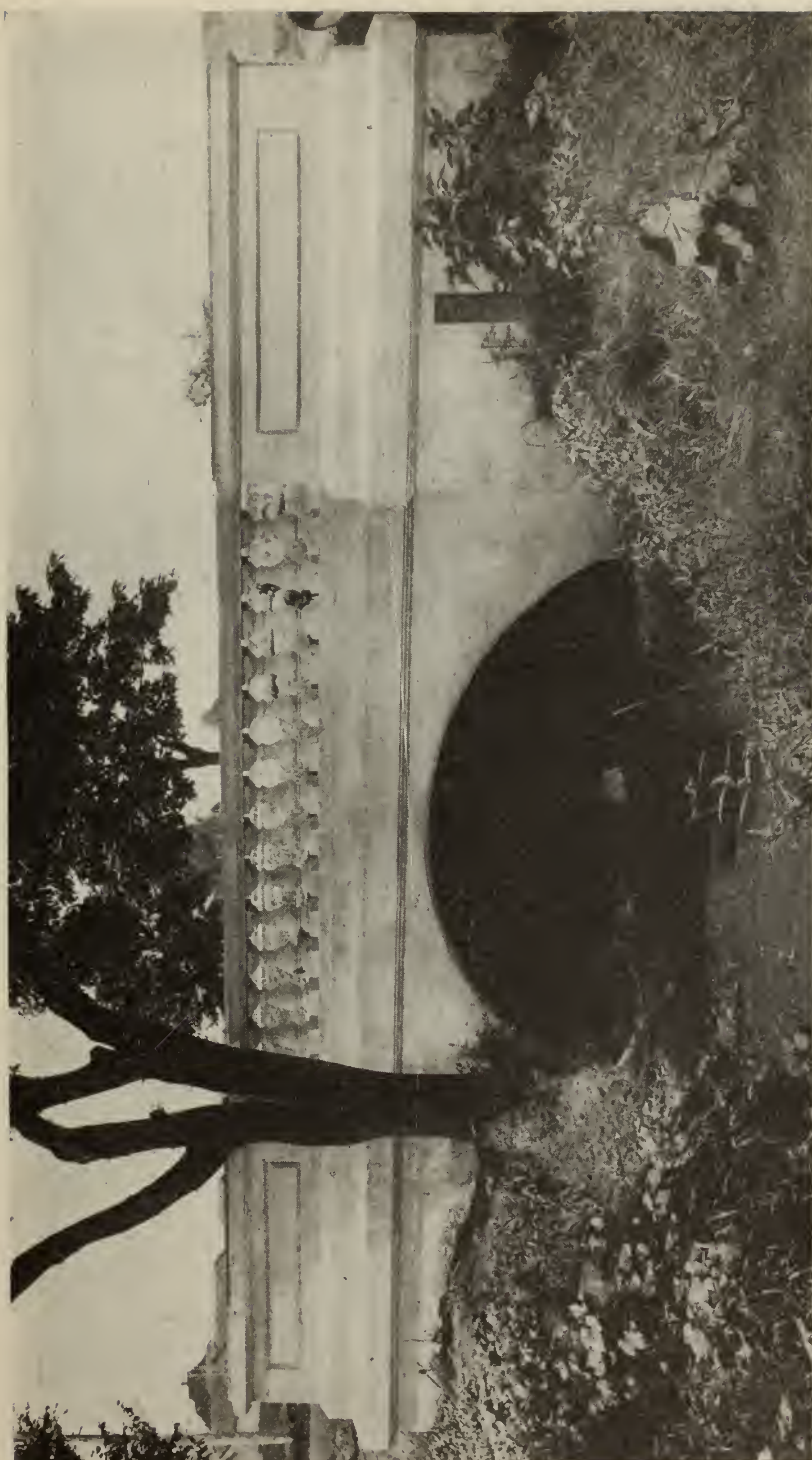
Such competition may prove objectionable on public work because of the difficulty of determining the lowest bidder when competing devices are under consideration. So the engineer is apt to take the easiest way of conducting the letting of the contract; requiring all bidders to submit prices on the same detailed plan, prepared by himself without regard to patent infringement, or economy, or excellence of construction.

In a new industry like reinforced concrete open to all bidders, such a method of letting places a premium on inexperience; and it is nearly always the incompetent bidder, who knows nothing of costs, that is awarded the contract. Under such conditions the trained bridge manufacturer and the bridge specialist must discontinue business, except for patent protection, and must see that business abandoned to sidewalk builders and others who never have done anything for the good of the industry and in all probability never will. What *is* desirable in this line of industry, as in every other line of manufacture, is open competition between experts. Instead of standing in the way of such competition, patent protection actually promotes it, provided the engineer will use a suitable method of letting the contract for the bridge.

If a plan for a patented bridge alone is placed on file, there is no means of knowing that the patented improvements are worth the royalty demanded; and if other plans are placed in competition with the patented bridge, it is impossible to determine who is the lowest and best bidder. If these were all the considerations that entered into such lettings it might be worth while to take a chance on infringement or lack of economy, and award the contract on a detailed plan on file whether patented or otherwise. But there are many other objections to this method of letting, and many advantages to be gained by a third method that not only removes all these objections but provides for competition on efficient designs without infringement by the engineer. This method of awarding the contract applies particularly to concrete arch bridges at public lettings.

DIFFICULTIES OF PUBLIC LETTINGS.

A reinforced-concrete arch bridge requires, above all else, expert designers; it also requires expert and responsible builders. In a public letting the award must almost necessarily be to the lowest bidder complying with the specifications, otherwise the opposition newspaper will raise a cry of graft at the instigation of the rejected bidder. When all bidders bid on exactly the same thing and with no technical qualifications necessary, the most inexperienced builder is almost sure to be the low bidder. The numerous errors made on the safe side are never detected but the one error on the side of



Twelve-foot arch, Fair Grounds, Des Moines, Iowa, small but harmonious.

Illustrating incompetent erection.

danger promptly secures the award. And the one who can make the worst error stands the most chance of securing the work. Such a method of letting in a new industry excludes the expert and actually penalizes him at every letting in which he participates. It secures but limited competition, that is, on materials and labor, but no competition whatever on what is actually being purchased—a bridge. It provides for no competition in design. The designer of the plan on file, himself will probably not be experienced because he will have been chosen by a board of laymen having no knowledge ordinarily of the qualifications required in an expert. It is as confusing for such a board to select the best expert as to select the best plan when several are submitted in competition at a letting.

The designer of the detailed plan on file, knowing that the contract will be awarded to the lowest bidder, usually below cost, must make his plans excessively heavy for safety, and then must inspect the structure himself with the closest care to see that the plan is not skimped.

The concrete-bridge business is unlike the steel-bridge industry, in that the former is open to every one while the latter has been, to a large extent, closed to the many because of the capital necessary to erect a suitable plant for manufacturing purposes. Because of the difficulties of embarking in the manufacture of steel bridges, and because of the plant required, steel-bridge building has been a business of experts to a far greater degree than is at present true of concrete bridges. The same conditions do not apply to designers of steel bridges, but the expert builder has served as a check on the incompetent designer. The fact that the manufacture and erection of steel bridges has been to the many a closed profession of expert engineering construction, is what has been giving steel-bridge construction its high reputation for efficiency, rather than the expert supervision of designing and consulting engineers.

This same safeguard is not present at all in the concrete-bridge business, and until some substitute is devised that will perform a similar service for this industry, the industry must suffer. A county may be building steel bridges satisfactorily under these conditions; then it may be induced to erect a concrete bridge by expert service, with pronounced success. Later, it may dispense with all restrictions and permit incompetents to enter the field, and after a period of five or six years' experience, the county may revert to steel bridges, and so on in cycles.

The day must come, of course, when the building of a satisfactory concrete bridge will forever end the building of temporary bridges, and result instead in a steady replacement of such structures by permanent concrete bridges; and that day will come only when the "public official" recognizes the fact that his engineer must be an expert designer and his contractor an expert builder of concrete bridges. The present difficulty is one inherent in all new in-

Illustrating unskilled design.

dustries and will be cured by education, by designers becoming expert, by builders becoming trained, and by the purchaser learning to distinguish between the expert and the incompetent. It will some day become largely a matter of reputation of the designer and of the builder.

As an example of how this matter may be badly handled, the state of Missouri has a law providing that a bridge may be let at public auction to the lowest bidder. The inexperienced bidder need but listen to the bids of those assumed to be experts and then bid a dollar lower to secure the award. He will readily overlook two most important considerations,—first that the next bidder above may not be a safe guide, and second, that if the bid is safe for an experienced builder it would prove a losing venture for himself, an inexperienced builder. Impelled by the belief that others are making tremendous profits, he takes the plunge and rarely emerges. But always another incompetent bidder takes his place.

A BETTER METHOD OF LETTING.

All of the above objectionable features may be avoided by inviting bids upon plans which show externals only of the arch bridge proposed, accompanied by the usual specifications, but which also specify the required loading and the allowable pressures and stresses; and requiring each bidder to submit the sectional details and guarantee the structure. In order to submit a bid under such an invitation, the prospective bidder must secure a detailed section that he will be willing to guarantee. This compels him to appeal to an expert designer. That there would be abundant designers appears from a recent competition at Fort Worth, Texas, where it was desired to employ an engineer to design and superintend the erection of a proposed reinforced-concrete bridge. There were eighty-four applicants. Some of these would-be designers are not experts, but competition between such designers selected by builders compelled to guarantee their designs, would tend to eliminate the incompetent.

By this method entire responsibility for the structure rests with the builder. The engineer is freed entirely from any responsibility as to infringement of patents. Competition is had between expert designers allied with expert builders, and the tendency is always to exclude the incompetent and thus encourage the survival of the fittest, instead of encouraging the destruction of those unfit. Yet the method of accomplishing this result is by thoroughly impartial requirements so that no charge of favoritism can be sustained. The bidder must of necessity have technical qualifications, and since the question of determining whether the submitted sections conform to the specifications is now a technical matter, the decision as to award rests with the engineer rather than with the board of non-technical laymen. It is an easier matter for the engineer to determine whether the sections conform to the requirements than for

Seventy-foot arch, Boulder, Colorado, without ornamentation, yet thoroughly harmonious.

a board of laymen to select an expert designer, and he has, besides, two additional checks, in the expert designer of the submitted sections, and in the guarantee. Whether or not such a guarantee is actually available as a final resource, is not of so much importance as that a contractor, bound by a presumably valid guarantee on his own submitted sections, will be compelled to exercise care in selecting his expert designer, and will endeavor to construct his work properly; whereas when the design is made by another and not guaranteed, he is offered a premium for poor workmanship.

Under this proposed method of letting, the award is made to the lowest bidder whose sections are properly designed, and thus retains all the advantages of the letting with detailed plans on file.

SUMMARY.

1. The reinforced-concrete arch approximates the ideal highway bridge.
2. Its most serious drawback is the intricate method of analysis necessary for its solution.
3. This objection may be removed by development of standard designs.
4. Standard designs require expensive analysis as a basis, with confirmation by field inspection of behavior of actual structures.
5. Patent protection on collateral improvements is essential to warrant production of standards.
6. Present methods of conducting public lettings restrict opportunities for expert arch design.
7. The proposed remedy is a method of letting in which the plans show externals only, the structural details being submitted by the bidder, conforming to detailed specifications.

DISCUSSION.

F. E. Davidson, M. W. S. E. (Chairman): This is an extremely interesting paper, and I hope that all will feel free to ask questions or take part in discussing it.

The author brought out a point, which I trust all engineers who are working with reinforced concrete will bear in mind,—namely, that a reinforced concrete girder or slab or arch, does not necessarily grow stronger with age. This is due to the fact that as concrete gets harder, the neutral axis is lowered, but the steel remains of the same strength as when it was originally placed. The result is,—theoretically, at least,—that the structure gets weaker with age, and not stronger, in my opinion. We often hear the statement that reinforced concrete construction is much stronger at the end of four or five years than when it was first installed, and continues to grow stronger. There is considerable doubt in my mind, however, of the truth of this statement.

I think Mr. Luten has given us all something to think about.

Arch design is a very interesting field, and Mr. Luten has explained very carefully and very thoroughly, the difficulties to be met in the design of concrete arches.

E. S. Nethercut, M. W. S. E.: It seems to me that the real subject is reinforced concrete, but the author has embraced an opportunity to say something with regard to the patent situation, which I think is really quite important for engineers. I have frequently met objections, on the part of engineers, to adopting designs which carry an alleged patent. Assuming that the patent is valuable, the real questions, as the author brought out in his paper, are: What is the advantage to the user of that patent? Will it really produce an economy; and if it does produce an economy,—which can be shown most conclusively by competitive bids by the patent designers,—why should engineers take a more or less neutral position with regard to recommending the adoption of the patented plan? Sometimes it is the case that they take a negative position; more frequently it is a neutral position, and it seems to me that there is an opportunity for engineers to do real good engineering work in coming out squarely upon that proposition, and using the economical plan, whether patented or not.

As Mr. Luten has stated in his paper, the entire object of the patent laws is to encourage invention and to give as a reward to the inventor a legal monopoly of his design or his invention for a period of seventeen years. This has been construed by our courts in various ways, so that the monopoly is a very questionable one. Sometimes the victory, if gained at all, is gained at a larger expense than it is worth. Recently there has been a patent decision by our Supreme Court, which has possibly strengthened the position of the inventor more than anything else that we have had in recent years. I refer to the decision in the A. B. Dick case. There it is held that the inventor has a right to his monopoly and a right to collect his royalty in any manner which does not interfere with the rights of others. In this particular case the inventor has assumed that the usefulness of his machine—being a copying press, called I think, the Neostyle—is measured by the amount of ink which is used, and he proposes that the royalty be paid on the installment plan as the ink is purchased.

This merely illustrates the fact that inventors are really trying to determine some justifiable and some equitable method of assessing the proportion of the usefulness of an invention. As engineers, I believe we should encourage the art by endeavoring to take positive positions, and recognize the value of improvements which have been made. In this field of reinforced concrete, which is of course new, there are yet many opportunities for valuable inventions, provided the engineer can find that his invention will return to him a value somewhat measured by

the skill which he shows in designing, and based upon the real principles underlying reinforced concrete construction.

W. G. Langenheim, M. W. S. E.: In regard to experienced designers being at a disadvantage at public lettings, this applies also to steel design. The "skinned" design is often accepted instead of a better one.

It may be of interest to know that on the Florida East Coast Railway, Key West Extension, after about eight years of experience, the engineers finally decided upon a type of concrete arch bridge that had no reinforcement. Instead of putting in steel, they put in a larger amount of concrete. The situation was responsible for this, due to the fact that warm salt-laden air is very destructive to steel, and they were not sure that steel encased within 1½ in., 2 in. or 3 in. of concrete, would be sufficiently protected against salt-water action.

The argument of the paper contrasts a reinforced concrete girder with a reinforced concrete arch, and gives the arch the preference, because there is bending action. It is just in this point of taking care of bending by steel, in place of using a deeper ring, that the reinforced arch differs from the plain arch, and the argument carried farther would give a plain arch the preference over a reinforced arch. This is right in harmony with the decision reached by the Florida East Coast Railway engineers. In this connection it is well to state that economy was a factor in adopting the plain arch as well as other considerations of design. The stone for their early reinforced arches was trap rock, brought from the Hudson River. In their later plain arch construction, they used coral rock, which is light and porous, blasted from the bottom of the sea, and used this with a rich mixture of cement. A deep arch was used. The arch was analyzed by the equilibrium polygon within the middle third, going right back to the old-fashioned method of arch computation.

I would like to ask whether, in the three analyses that were shown, if it could not have been possible that one of the engineers, in his calculations, took the pier into consideration, or whether all three men started from the skew back? This appears to me to be a point wherein they might have differed.

Mr. Luten: All three men started their computations from the skew back.

Mr. Langenheim: Starting from the bottom of the pier would modify results materially.

Mr. Luten: Unquestionably. That is one of the important points in the design of such a structure; but the city engineer made the assumption, in the first place, that the spring lines were fixed. When the reports were requested from the other experts, that same condition was included in the requirements, so that

all three analyses were made with the same conditions as to the skew back, the pier being considered a rigid body.

It occurred to me, when the point was raised that the Florida East Coast Railway used no steel in their more recent construction, that they had used enough in the earlier structures to make a good average.

I very much doubt whether there is any justification whatever for supposing that steel embedded two or three inches in concrete will be affected by salt water. The chemical action producing rust is not yet well understood, nor is the theory of protection of steel from rust by concrete understood. But we do know that carbonic acid gas, combining with moisture, causes rust in some way, and we also are quite certain that the hardening of concrete is due to the absorption of carbonic acid gas. It seems reasonable to suppose, therefore, that the reason that steel is not rusted when embedded in concrete, is because the concrete absorbing the carbonic acid gas prevents it from reaching the steel, and this would be true, even if small cracks occurred in the concrete and penetrated to the steel. It there is anything in that theory, I doubt whether even warm salt water would have any effect on the embedded steel.

L. J. Mensch: The student of reinforced concrete arch bridges, and those who have as yet only limited experience in the design and construction of such bridges, will find much in Mr. Luten's paper which has not appeared in print heretofore, and a very careful and repeated study of this paper will warn him of many mistakes which he could inadvertently make.

The paper contains, however, many statements which must be controverted.

The author declares that reinforced concrete girder bridges should be used only for spans less than 30 ft., and that they compare unfavorably with arch bridges, because an increase of strength of the concrete does not help the girder as much as the arch. While the increase of strength is probably not as great in the girder as in the arch, yet in properly-designed reinforced concrete arches, the bending moments from the live loads and the change of temperature, etc. are so large that the arch must be considered as a girder as well, and therefore we cannot ascribe a much larger increase of strength to the arch than to the girder.

It is a fact that in many arch bridges the cost of the abutments is much greater than the cost of the arch proper, especially where there is a poor soil condition, and for this reason the writer thinks that the use of arch bridges in preference to girder bridges, up to 60 ft. span, is largely determined by soil conditions.

Although it is known by very many tests, made in the last fifteen years, that high carbon steel reinforcing gives greater ultimate strength than the mild steel reinforcing, still, the author claims

that high carbon steel is objectionable in reinforced concrete construction.

The statement of the author, that reinforced concrete arches are as difficult an engineering structure as has been devised and that the elastic theory, as applied to reinforced concrete arches, is still in its elementary stages of development, must be controverted and only shows that the author is not very familiar with the elastic theory. The writer can state that, in his opinion, it is a much more difficult task to find the exact stresses in the common Fink truss made up of angle irons, considering the eccentricity of all connections, which is wrongfully neglected in the common design, than the figuring of the reinforced concrete arch by the elastic theory.

The so-called elastic theory was first brought to our attention by Castigliano in his book which was published about 1857. The method shown by Castigliano is very exact but requires very tedious computations and a great amount of time. Inasmuch as the elastic theory is the only way by which we can determine the stresses in an arch, engineers of great reputation, especially in France and Germany, have been elaborating with great success simplified methods for nearly forty years. I will only mention the well-known names of Winkler, Mohr, Müller-Breslau and Melan.

Let x and y be the co-ordinates of any point of the arch, assuming the origin of co-ordinates to be at the intersection of the center line of the arch with the left abutment.

E the modulus of elasticity

I the moment of inertia at x-y

F the area of the section at x-y

M the bending moment at x-y

ds, dx, dy, the increments of the length of the arch and of the ordinates of x-y

l the span of the arch

f the rise of the arch

d the depth of the arch at the crown

N the normal component of exterior forces at the section x-y

H the horizontal component of the thrust

R the reaction at the left abutment

M_a the bending moment at the left abutment

p the load per square foot

c the coefficient of temperature expansion for 1 deg. Fah.

t the change of temperature in degrees Fahrenheit.

Then the elastic equations commonly quoted for an arch without hinges are:

$$\int_{x=o}^{x=l} \frac{Mds}{EI} = 0 \quad \cdots\cdots\cdots (1)^*$$

*Howe's Treatise on Arches.

$$\int_{x=o}^{x=l} \frac{N}{EF} dy + \int_{x=o}^{x=l} \frac{Mxds}{EI} = 0 \; ; \ldots\ldots\ldots\ldots\ldots (2)$$

$$\int_{x=o}^{x=l} \frac{N}{EF} dx + \int_{x=o}^{x=l} \frac{My}{EI} ds = 0 \ldots\ldots\ldots (3)$$

Equation (1) will be recognized as the common formula for the change of angle between the tangents of two points of a simple beam and simply means that there is no change of angle between the tangents of the arch at the two abutments. Similarly, Equation (2) means that the relative vertical displacements of the two abutments equal zero. Equation (3) means that there is no change in the horizontal distance between the two abutments. Until a few years ago most investigators assumed a constant ratio of $\frac{ds}{I}$, which allows of easy integration of above equations and results in comparatively simple expressions of the three statically unknown values of H, R, and M_a for a concentrated load P, distant u from the left abutment of a parabolic arch.

$$H = \frac{15}{4} \frac{P\,(l-u)^2\,u^2}{l^3 f \left(1 + \frac{45}{4}\frac{I}{f^2 F}\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$R = P \; \frac{(l-u)^2\,(l+2u)}{l^3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$M_a = P \; \frac{u(l-u)^2.}{l^3} \left(l - \frac{\frac{5}{2}u}{1 + \frac{45}{4}\frac{I}{f^2 F}} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 6)$$

and the bending moment at any point $x—y$ to the left of P is
$M = Rx - Hy - M_a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$
and the bending moment of any point $x—y$ to the right of P
$M = Rx - Hy - M_a - P\;(x-u) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$

The expression $\frac{45I}{4Ff^2}$ represents the influence of the shortening of the arch. For a width of one foot of the arch

$$I = \frac{d^3}{12}$$

$$F = d$$

$$\frac{I}{F} = \frac{d^2}{12}$$

$$\frac{45}{4} \cdot \frac{I}{Ff^2} = \frac{45}{4} \cdot \frac{1}{f^2} \cdot \frac{d^2}{12}, \text{ or approximately } \frac{d^2}{f^2} \qquad \text{(9)}$$

showing that the influence of the shortening of the arch increases with the square of the thickness of the arch and decreases with the square of the rise of the arch.

Engineers familiar with influence lines will be able to find the influence lines for the bending moment for five or ten points of the arch by means of equations (4) to (8) in less than two hours' time, and these influence lines are the same for any span and any rise. They can be found in the writer's Reinforced Concrete Pocket-Book. By means of the influence lines the most unfavorable location of a group of concentrated loads can be found in a few minutes. In most highway bridges the most unfavorable loading assumed is a uniformly distributed load of 80 lb. to 100 lb. per sq. ft. on half of the span from an abutment to mid-span. We can obtain the unknown values of H, R, and M_a for this case by integrating equations (4), (5) and (6) between the limits $u=o$ and $u=\frac{l}{2}$ and easily find that in this case, M_a is the absolute maximum moment which occurs in the arch and equals $\frac{pl^2}{64}$, and the relatively maximum moment between abutments equals $\frac{9pl^2}{1024}$ and occurs at a point $5/16l$ from the left abutment. A negative moment of the same value occurs at a point $5/16l$ distant from the *right* abutment. Where the thickness of the arch is relatively small and the rise greater than ⅛ of the span, the shortening of the arch and temperature stresses may often be neglected, and the arch figured only for two moments

$$\frac{pl^2}{64} \text{ and } \frac{9pl^2}{1024} \qquad \text{(10)}$$

at abutment and the 5/16 points of the arch, respectively.

Even where influence lines are used for concentrated loads, the figuring of an arch for both concentrated loads and uniform loads should not take more than a few minutes' time and not days or weeks, as stated. There have been many bridges of considerable span designed on this principle, built more than twenty years ago, tested under rigid government inspection, and which are free from cracks so often found in similar bridges in this country.

It may be objected that the above short method holds true only

in cases where the dead and live loads are nearly uniform so that a parabolic line of pressure may be assumed, and that it is still a laborious undertaking to find the proper line of pressure in an arch with earth fill.

In regard to the line of pressure in such a case, it was also solved about seventy years ago by G. Hagen, but involves the use of periodical functions, for which only very few tables are in existence. The writer, therefore, evolved an approximate method which is probably more correct than any graphical method ever evolved, and the ordinates of the line of pressure may be found by the equation

$$y = \frac{8f_1}{1+6\frac{a}{f}} \left\{ \left(1+3\frac{a}{f}\right)\frac{x}{l} - 3\left(1+\frac{a}{f}\right)\frac{x^2}{l^2} + 4\frac{x^3}{l^3} - 2\frac{x^4}{l^4} \right\} \quad (11)$$

when a=the weight of the bridge at the crown per sq. ft. plus 50 lb.
f=the weight of the bridge at the abutment per sq. ft. plus 50 lb.

Tables for the values of y and for various values of $\frac{a}{f}$ may be found in the writer's Reinforced Concrete Pocket-Book. By means of this table it takes only a few minutes to find the most favorable shape of the arch.

A further objection may be offered to the short method shown by the writer, that in case of a small rise the influence of the shortening of the arch and of a change of temperature is still a hard stepping-stone to full confidence in this method.

The influence of a change in temperature is found by replacing zero in Equation (3) by the value of ctl, and by integrating we obtain the simple expression for the change of thrust

$$H = \frac{45}{4} \frac{EIct}{f^2} \quad \text{. . . . .} (12)$$

Substituting, E=1,500,000,
c=.0000055,
t=40 deg. Fah., then

$$H = 3710 \frac{I}{f^2} \text{ lb} \quad \text{. . . . .} (13)$$

when I and f are in inches, and

$$M_a = 2500 \frac{I}{f} \text{ inch-lb} \quad \text{. . . . .} (14)$$

The distribution of bending moments in the arch can be easily found by assuming H acting in a horizontal line $2/3f$ above the abutments.

Where the shortening of the arch is neglected, the line of pressure for a uniform load in a properly designed arch is supposed to

pass through the center of gravities of the sections at the crown and abutments.

The shortening of the arch causes, in the line of pressure, when the arch is uniformly loaded, a rise at the crown of

$$1/3\,\frac{d^2}{f} \qquad (15)$$

and a fall at the abutment of $2/3\,\dfrac{d^2}{f}$ . . . . (16),

which values, multiplied by the proper H from the load which causes shortening of the arch, represent at once the bending moments caused by the shortening of the arch. If the live load is only on one-half of the arch, the ideal rise at the crown of the line of pressure is again $1/3\,\dfrac{d^2}{f}$, while the fall at the left abutment, if the live load alone is considered, $=\dfrac{11}{12}\,\dfrac{d^2}{f}$.

We obtain the bending moments from the shortening of the arch, when only one-half of the arch is loaded, by multiplying the thrust $H=\dfrac{pl^2}{16f}$ by $\dfrac{1}{3}\,\dfrac{d^2}{f}$ at the crown, and $\dfrac{11}{12}\,\dfrac{d^2}{f}$ at the left abutment.

To sum up, the figuring of most reinforced concrete arches by the elastic theory is not so difficult a matter as would appear from Mr. Luten's paper. In most bridges of open spandrel construction, a parabolic line of pressure may be adopted and the horizontal component of the thrust found by $\dfrac{pl^2}{8f}$.

The greatest bending moment from a uniform load on one-half the span is $\dfrac{pl^2}{64}$ at the abutment, and $\dfrac{9pl^2}{1024}$ at $5/16l$ from the abutment, *positive at the loaded side* and *negative at the unloaded side*. The change of thrust from a rise or fall of temperature equals $3710\,\dfrac{I}{f^2}$ lb. and the moments can be found by assuming this thrust to act at $2/3f$ above the abutment.

The influence of the shortening of the arch on the bending moment is found by multiplying the proper thrusts by the simple expressions $\dfrac{d^2}{3f}$ and $\dfrac{11}{12}\,\dfrac{d^2}{f}$ for crown and abutments, respectively.

For earth-filled arches we can find the ordinates of the pressure line by the formula (11), and the corresponding thrust by the formula $H = 100 \frac{l^2}{48}\left(1+6\frac{a}{f}\right)$ per lineal foot.

There may still be a question in the minds of many engineers as to the adaptability of the above equations to arches where $\frac{ds}{I}$ is not constant. The writer found that the elastic equations (1) and (3) admit of comparatively easy integrations when $\frac{ds}{I}$ increases uniformly from the crown to the abutment in the ratio of 1 to 8, which is the case when the thickness of the arch at the abutment is approximately twice that of the crown. In this case the greatest moment from a uniform load at half the span is again at the abutment and greater than in a uniform arch, and equals $\frac{pl^2}{40}$, and the relative maximum moment in the arch proper is at $0.35l$ distant from the abutment and equals $\frac{9pl^2}{1600}$, hence smaller than in an arch of constant $\frac{ds}{I}$ (neglecting the shortening of the arch). The influence of the shortening of the arch becomes considerably greater and the rise of the pressure line at the crown, due to an ideal uniform load on half the span, equals $\frac{5}{7}\frac{d^2}{f}$ or about twice the value in a uniform arch, and the ideal fall of the pressure line at the left abutment equals $\frac{74}{14}\frac{d^2}{f}$ instead of $\frac{11}{12}\frac{d^2}{f}$.

Also the thrust from a rise or fall of temperature of 40 deg. Fah. is considerably greater in this case, and equals $17000\frac{I}{f}$ when I, the moment of inertia of the crown section in inches and f the rise in inches, or 4½ times as great as in a uniform arch; the moments about any points of the arch can be found by assuming that this thrust is acting at $0.833f$ above the abutment, and the average increase of stress at the abutment is very close to 40% from a change of temperature. The simple expression for the change of thrust for a rise or fall of temperature shows clearly that it is directly propor-

tional to the moment of inertia of the crown section, or to the cube of the thickness of the arch. Inasmuch as the stress from shrinkage of the concrete, which continues often for three or four years, is nearly as great and often greater than the temperature stresses, it is very important that arches be designed with the least thickness compatible with safe construction, otherwise unsightly cracks so often complained of in concrete arch bridges will always appear. Stresses from the shortening of the arch and temperature and shrinkage stresses are, in most arches of American design, much greater than the live and dead load stresses, except in arches of very great rise.

For any other increase of the thickness of the arch towards the abutment, the corresponding values for the design may be found by interpolation with the values for uniform $\frac{ds}{I}$ and for an increase of $\frac{ds}{I}$ in the ratio of 1 to 8.

Mr. Luten's suggestion for standards for reinforced concrete arches is a very good one, and a great many may be found in the writer's Reinforced Concrete Pocket-Book, and there is no doubt that within a short time the highway bridge commissions of the various states will be able to furnish to the various communities good designs at nominal costs. Only, these standards will have to be changed from year to year, in order to keep in line with the improvements of the art.

Improvements are needed, not in the design of the arches, but in the method of building arches so that the costly form work is diminished to a minimum, and much greater care should be given to the design of the concrete piers and abutments than is at present given to them; any improvements in connection with the abutment are more important than those in connection with the arch, as long as the arch is designed on the lines shown herein.

Mr. Luten: Mr. Mensch's mathematical labors remind one of the fable of the mountain and the mouse. His several pages of formulae apply only to the parabolic arch. It has long been well-known that the elastic theory becomes extremely simple when applied to an arch of parabolic form, but unfortunately such an arch has extremely limited application. It is never an efficient structure save when its fixed loading is of uniform horizontal distribution. This condition occurs very rarely in practice. The writer has supervised the design of approximately 12,000 reinforced concrete arches, of which upwards of 5,000 have been erected, yet he has never in a single instance employed an arch of parabolic form.

The parabolic arch may, of course, be applied to *any* distribution of loading and its analysis still remain a simple problem of a few hours' time. But the moments in the arch ring may become so great, that the arch must be designed much thicker and with

heavier reinforcement than if the arch were properly designed to be in equilibrium under the given loading. A properly-designed arch has no dead-load bending moments. The parabolic arch is of sharpest curvature at the crown and is flattened at the haunches, whereas the proper curve for an earth-covered arch is the reverse,—sharpest in curvature at the haunches and springing, and flattened at the crown. The parabolic arch has its thrust against the abutments more nearly horizontal, and hence requires heavier abutments than the proper linear arch for such loading. It also restricts the waterways. It cannot compete in cost with a properly-designed circular arch except for those exceptional cases when its fixed load has uniform horizontal distribution.

The parabolic arch may have its uses for those engineers who refuse to apply the necessary mathematics to a proper solution of an efficiently designed structure. In this respect it is like the three-hinged arch, which is a very simple structure in analysis, but not at all a competitive structure in cost of erection. It is not surprising that Mr. Mensch should say, when considering the parabolic arch, that it cannot compete with a 60 ft. girder under unfavorable foundation conditions. But it by no means follows that a similar comparison would hold for an arch properly chosen for efficiency under its fixed load and then analyzed by a general application of the elastic theory, and not restricted to a particular curvature, or ratio of $\frac{ds}{I}$ in order to reduce the labor of analysis. The writer firmly believes that a properly-designed reinforced-concrete arch will prove of lower cost than a properly-designed slab or girder for the same loading *for all spans* and *for all conditions* of foundations. It is quite possible, of course, that for certain conditions of difficult foundations, the abutments of an arch might cost more than the arch itself; but the cause would necessarily be wet excavation, piling, pumping, sheeting, etc., which would also be necessary, to some extent, in the case of a girder, and it would in almost all such cases be equally true that the abutments of the girder would cost more than its superstructure. The girder is a simple structure that can be analyzed by any engineer, whereas the properly-designed arch requires an expert; it very naturally follows that one who is not an expert in arch design will attribute greater efficiency to the girder, than is its proper due.

Mr. Mensch's formulae—simple as they become for the parabolic arch—are not even approximately correct if any considerable amount of tension occurs in the arch ring. The numerous foreign authors on whom he relies have all assumed stress proportional to strain for the determination of the pressure line, but this assumption fails for any considerable degree of tension and upsets all the values of I throughout the regions of tension.

Mr. Mensch deals only with a very narrow application of the elastic theory, and treats it in such a way that the novice will be led to believe that it has general application, which is very far from the truth. His formula (11) for an earth-filled arch does not have broad application, but is limited to an arch of peculiar and inefficient form which cannot be accurately analyzed by the short method he employs, and must be given the general treatment of the elastic theory requiring several days of computations.

Temperature stresses in arches, when determined by the usual method outlined in text-books on the elastic theory, have always been the bug-bear to frighten the novice in arch design. In almost every case the authors of such texts, although approaching the subject only from a theoretical standpoint, have avowed their disbelief in the temperature results and have intimated that something was wrong with the assumptions. The writer has already quoted Professor Howe on this subject. He has also called attention to the fact that if the concrete girder and its abutments be analyzed as an elastic arch, it will show much greater temperature stresses than the arch. It may be added that, although the worst conditions of stress in the arch usually result from the combination of concentrated load with low temperature, yet no arch has ever been known to fail under such conditions. Again, the heavier the sections of an arch, the greater the temperature stresses, since the stress varies approximately as the square of the arch thickness. If, then, for a properly-designed arch the temperature stresses are so serious, what must happen when arches are built, as frequently occurs, with from two to three times the required thickness. Yet even such heavy arches show no serious temperature defects. The cracks that are found in arches are nearly always due to *vertical* and *unequal* settlement of foundations.

The writer is unable to see the force of the statement that, because of the large bending moments in a properly-reinforced arch, it must be considered as a girder as well as an arch, and that, therefore, it gains no more increase of strength with increased age than the girder. The *distinction* between an arch and a girder is that the former is subjected to both thrust and moment, while the latter resists moments only. Temperature moments are greatest in flat arches but so, also, are the thrusts. The arch cannot be treated as a girder unless the *thrust* is entirely eliminated; and it is because of the *presence* of thrust that the arch is enabled to grow stronger with increasing strength of the concrete in compression. It is the *absence* of thrust in the girder that limits its increase in strength to that of the steel. It is useless to argue that the arch may be treated as a girder unless it is made into a girder by elimination of its thrust. It would be quite as sensible to argue that a column subjected to moments might be treated as a simple beam.

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There have been many improvements in arch design within the past fifteen years; there have also been numerous improvements in forms and centering; many valuable patents have been issued during that period for such improvements. Without improvements the reinforced-concrete arch could hardly have become a successful competitor of steel bridges, as it assuredly has within the past five years.

LIGHT COMPRESSION MEMBERS.

TOPICAL DISCUSSION, MARCH 11, 1912.

Bridge and Structural Section.

Horace E. Horton, M. W. S. E.: I have just one thing to urge in connection with the details of compression members,—not necessarily light members, but all members. The error I discover is that the principal part of our discussion turns on the radii length, while it has developed, with the built-up members universally used, that the composition of the section has more to do with its efficiency than its radii length.

Our knowledge of column design has been evolved from laboratory experiments on solid rounds and small pipe, made approximately eighty years ago. The laws of flexure for rolled sections were fairly well developed by these early tests; in fact, we have repeated examples justifying the laws of flexure as set forth in the formulæ. In the evolution of things, however, we have come to build compression members that are not rolled but are composite structures, usually of plates and angles. We may use channels or we may use beams, but practically speaking, the members are built up of plates and angles. There are specifications in general use that allow a greater compressive than tensile stress per unit section of the same material. It was this error that culminated in the Quebec disaster. Compression members of forty radii were used with as great a unit stress as that allowed for tension, and in some cases a still higher unit stress was allowed on these compression members. As a matter of fact, the compression members of that structure failed with one-quarter the unit load that the material would have sustained in tension. Now, it failed how? Not by flexure, but by the wrinkling of the component elements.

Another engineering society started, some years ago, to gather all available statistics with reference to compression members. The committee of that society concluded that laboratory tests were of no value and they found, altogether, 268 recorded tests of large compression members, 184 of which were of iron and almost obsolete, except as illustrating general laws. A second group of 52 tests were made on rolled sections, namely, pipe and **H** sections. The tests of this second group undoubtedly show the maximum efficiency possible in a compression member. Each one of a third group of 32 built-up members failed by wrinkling of the parts. Not one of them yielded by flexure. In other words, none of the tests of which we have record shows a built-up member which was so designed as to reach its maximum efficiency.

We are left with the question: Suppose two, or three, or four times as many rivets had been driven through the angles and plates;

or again, suppose that rivets of twice the area had been used. Would the members have sustained a greater load? Would we have obtained a greater efficiency from the material by using more or larger rivets?

What we want instead of 32 is more than 1,000 tests, varying the constituent elements such as radii length, size, and number of rivets. It happens that the members of this third group of built-up members represent about 65% efficiency, as compared with the rolled sections, at their point of failure. The loss is 35%, and it is here that experimental research can point the way to better design. We will have to have a large number of tests to give us the knowledge necessary to design to the best advantage.

Because the cost of a sufficient number of tests of full-sized members is prohibitive, I am personally inclined to think that laboratory tests are all that we can hope to get in sufficient number. Suppose we use a built-up section of two plates, 4 by ⅛ in., four angles ¾ by ¾ by ⅛ in., varying the size of the lacing and the size and number of rivets as the research advances. This section would have a gross weight of, say, 8 lb. per lineal ft., would have a radius of gyration of 1.5, and a sectional area of 1.42 sq. in. The length for $24 \frac{1}{r}$ would be 3 ft., and for $240 \frac{1}{r}$, would be 30 ft.

If we should make tests of five members of each of these lengths and eight intermediate lengths, we should have 100 tests which would undoubtedly point out many valuable facts. By making 1,000 tests in all, it would probably be possible to discover the spacing and size of rivets to make the material fail by flexure rather than by wrinkling.

The Pennsylvania Lines (Panhandle) not long ago made elaborate tests of six large members about 40 ft. long, each nearly 100 sq. in. in cross section. The material for these tests alone represented some 80,000 lb., or about the equivalent of the material required for the 1,000 tests suggested above.

I believe that we are safe in concluding that there is no mere mental analysis that will ever show us the required relations. Physical tests are required. We have only 32 tests of full-sized steel members in all the years that have gone. These members were all designed on the theory that they would fail by flexure. They all did fail by wrinkling. Failure by wrinkling invariably indicates a low efficiency and a poorly designed member. Sections such as I have indicated can readily be handled in our University testing machines. At the University of Illinois, as at other engineering colleges, there are ambitious professors and active students. Give them a chance. I believe that if this Society would become interested in the subject, it would be possible to actually devise means whereby 1,000 such laboratory tests could be made, thereby adding more to

our knowledge of the compression member than we could hope to obtain in any other way.

F. E. Davidson, M. W. S. E.: In this discussion I trust some one will take up the question of a rather long compression strut with light loading, and show us how he would build an economical strut out of ordinary stock sections. That is a problem that architects and engineers have to meet constantly. The requirements of our revised building code with regard to compression members are very rigid compared to what could be done a few years ago. There are certain credits given to steel that is encased in concrete under certain conditions; that is, one can use a higher stress in certain types of columns than in other steel shapes with the same amount of concrete fireproofing.

When I was with the Illinois Steel Company I often used, in struts between roof trusses, a light channel with a plate riveted to one flange. For instance, with a 7-in. channel I would use a 7-in. plate and run the plate about three-quarters the length of the channel, simply to stiffen it sidewise. It is true I do not know of any case in which this section was used where the unit stress in the steel was over 3,000 to 4,000 lb. per sq. in. That was not economical; it was wasting steel; but it was the best we could do. I have used a 5-in. I-beam with a 4-in. channel riveted to the web. The channel has no office to perform, whatever, except to stiffen the I-beam section. The latter takes the entire loading. This section of a column is one that can be put in an ordinary 4-in. partition in an apartment building.

Recently the Lally column has come into use, which is nothing but a steam pipe filled with concrete, and it is my opinion that it might as well be filled with sand. The star-shape section, made of two angles, is very weak in one direction, on account of the very small radii.

Today we are confronted with the proposition that we have not, nor can be build, an economical rigid section for very light loads. Take, for instance, wind bracing. It is easy enough to provide a suitable section for heavy loads, but with light loads it is a different matter. In our building designs of today, for instance, the columns in the top story of any building, a 5-in. **H** section would support every load, but you cannot get it and what will you use in its place? As a matter of fact, I doubt if the manufacturers of steel have kept pace with the demand for economical sections along these particular lines. I understand that the Illinois Steel Company are developing these sections, and are making rolls for a new set of beams throughout; also that they are developing some very small, light sections, and are changing the moments of inertia and the weights of standard beams from 8 to 24 in.; so that very soon we shall have a new series of steel structural shapes to figure on. This is all right for floor construction, but what I am

after is something that we can use for columns and struts, which is economical; where the steel can be actually stressed up to a working limit of, say, 10,000 lb. per sq. in. Heavy column sections may be built out of a number of structural shapes, but in the light sections we are compelled to waste material, no matter what we use.

Albert Smith, M. W. S. E.: I am quite unequal to suggesting any section that would be thoroughly economical in the case which Mr. Davidson mentions. We use channels, light channels, with angles at the bottom in an endeavor to make the actual fiber stress come as near as possible to that permissible in such a case. It has sometimes occurred to me that it would be possible to use a pipe section in cases of that kind. If we could get pipes 18, 20, or 24 ft. in length of thin material, and could manufacture a standard detail for the end, to be threaded onto the pipe, we might be able to carry these very light loads economically. I think we are too much afraid of doing shop work, in general; we think a little too much of the cost of coping and of blacksmith work. With us, with the very excellent machinery that we use, the cost of shop work cannot be anywhere near as great as with English manufacturers. I refer especially to the small compression members of a bridge brace—those which we now make of single angles. English designers use T-bars almost exclusively for such struts, cutting off the outstanding leg, and I think such members could be used economically in our trusses. The cost of coping would not be great and we should avoid, in most cases, the gusset plate. Nine times out of ten two rivets are sufficient for a connection, and the two rivets could be driven through the remaining leg of the T-bar into the top chord.

In regard to large compression members—those to which Mr. Horton has referred—I wish that such tests could be made by the Government, and that when they are made they would parallel the case of the members in the field—for instance, the vertical posts of railway bridges. It seems to me they would be better if tested in connection with the floor beam, and it does not seem impossible to put bending in that floor beam while the test is being carried on. It should be braced with a knee brace at the other end in just the way the bridge in actual service is braced, and then we might find an answer to a question which is as yet entirely unanswered in specifications or in practice: What constitutes free length? I have in mind a set of specifications which permits three definitions; fixed at both ends, fixed at one end and free at the other, and free at both ends, and allows the free length to be made one-half, two-thirds, or the whole of the distance between connections on that basis. I do not know what constitutes a fixed-end connection in an actual structure; it seems to me it would be very hard to determine, and also very hard for anyone to say in a given case that he is willing to take one-half the length between connections as the free length of his member. There are so many things that enter into the stiffness of

the member, in the connection, the yielding of the support, the rigidity of the attachment, that it seems as if a test, which would simulate actual conditions and show the actual value of the compression member under those conditions, would be very valuable. The difference in the permissive fiber stress is likely to run as high as 25% or 30%, according as you vary the free length—that is, supposing you use the ordinary formula, $16{,}000 - 70 \frac{l}{r}$, and 30% is a rather important amount in the design of your member.

I have no suggestion that bears directly upon the subject that the chairman has in mind.

Henry E. Vanderlip, M. W. S. E.: In listening to Messrs. Horton and Smith, a few things have occurred to me. First, in regard to the question of wrinkling referred to by Mr. Horton. I have seen columns with that wrinkling between rivets, produced by heavy loading. There would seem to be a bulging out between the rivets, and yet the rivets had been spaced according to the so-called practice, which ordinarily is that no ¾-in. rivet—which is the standard rivet used in bridge and building construction—shall be placed at a greater distance than sixteen times the thickness of the thinnest outside piece of the member. This would mean that a ⅜-in. plate would be the minimum thickness where 6-in. spacing could be used, and a 5/16-in. plate, according to the rule, would permit not greater than 5-in. spacing. Yet if you use that same 6-in. spacing with a ⅜-in. plate under some conditions of loading, you will get a bulging or wrinkling of the plate. According to the formula, it should not bulge. That is one of the peculiar things in the construction that nobody has ever seemed to explain.

The subject that the chairman brought up, about the advisable form of column for light loads and long lengths, is one which has not often been brought before the engineering profession. We might consider two forms: First, a post or column under four points supporting a water tank—a gravity tank—placed 25 ft. (approximately) above the roof of one of the standard warehouses as they are built in Chicago. There are all kinds of forms of columns used, and it does seem as if the engineers should agree on some standard form that seems to be the most economical for that purpose. You will see a dozen different forms to carry, say, a 25,000 gal. water tank. I have known of cast iron being used for that purpose, but personally I would not select it. I have seen two channels used so as to form, with cover plates, a box-shaped column. Then I have seen four angles with a single web plate, which we all know has unequal radii of gyration on the two axes. Then I have seen star-shaped forms, and the star may be formed by using two or four angles—two angles of sufficient area to take a light load—and increasing those two angles in thickness and in the

size of the leg of the angle until we reach a point where good judgment would say you should use four angles as the load increases. I think this is a very good form of column for that purpose, for the reason that a water-tank tower is essentially a wind-braced structure. Therefore, since it is a wind-braced structure, one can arrange the position of the wind bracing horizontally and diagonally so that the question of the radius of gyration does not really enter into it. Another thing, the gusset plates can be arranged in between the angles, and the connections, from a bridge shop point of view, are about as good as can be obtained.

The other form I have in mind is a long column. Imagine a column, say 40 ft. long, in the middle of a large and high room, with an upper floor and roof of the building carried on that long column. According to the building ordinance, if the column is to be fireproofed with tile where the tile did not aid in stiffening the column, then the radius of gyration of that column should be 1/120 of that length; or, 40 ft. being 480 in., there would be a radius of gyration of 4 in., and the engineer would select a form of column where he would have a radius of gyration of 4 in. The form is a matter of preference. Probably in a case like that the average engineer would select a box-shaped column, as it is easier and cheaper to get a radius of 4 in. with the box shape by using channels and cover plates.

J. Norman Jensen: It might be advisable for me to review some of the features of the ordinance in regard to columns. As you probably know, the ordinance formula for the allowable stress is $16{,}000-70\frac{1}{r}$, and if the column is filled with concrete, and also encased with concrete, so that there is at least 3 in. of concrete outside of the metal, there is permitted an allowable stress of $18{,}000-70\frac{1}{r}$, but not to exceed 16,000 lb. In the first formula referred to, the limiting stress is 14,000 lb. These are the highest stresses that can be used, and the limiting length of the compression member is 120 times the least radius of gyration. You will find, if you want to use an I-beam column, as is sometimes advisable, say a 6-in. I-beam, you could not use a length more than 7 ft. 2 in., and if you had an ordinary ceiling height of 10 ft., or a little more, you would have to use a 15-in. I-beam, 42 lb. per ft. This 15-in., 42-lb. I-beam would be insisted on, even for the top floor of a building where there is only a light roof load, because we have only the ordinance to go by, and that is the requirement of the ordinance. In order to meet the condition for slender columns, the Lally and the Acme columns have grown into use under the protecting wings of the ordinance. Where you would

have to use, say, a 15-in. I-beam, 42-lb., you could use a Lally column or an Acme column 4½ in. in diameter, and satisfy the requirement as to length. Probably most of you know that these columns are merely pipes filled with concrete under pressure. In the city of Chicago there are two types—the older form called the Lally column, and another form called the Acme column—a recent competitor. While, of course, we cannot show any preference, we find that the details of the Acme column are considerably better.

The reason for bringing up this topic of light compression members, and the cause of this discussion about the limiting length of compression members, is that in apartment-house work in particular we want a column to fit inside of a partition. A 15-in. 42-lb. I-beam will not go inside of that partition, and so the architect and the engineer are compelled to use these round forms of columns, in order to comply with the rule in regard to limit of length. We would like to see the ordinance changed. We would like to see the limiting length increased from 120 to 150 times the least radius of gyration. This would allow the use of I-beam columns which are now practically excluded in buildings. The average round pipe column is of rather flimsy construction. There is no stiffness or rigidity about it. The use of an I-beam column for light loads will give something that is fairly stiff, and will be a section to which an I-beam can be riveted or bolted.

Tests at the Watertown arsenal, and other places, show that the radius of gyration has practically nothing to do with the strength of the column. The recent tests at the Watertown arsenal show, for the lengths tested (from 25 to 175 times the least radius of gyration), that there was practically no difference in the strength. The one at 25 was just about as strong as the one at 175 times the least radius of gyration. So it seems that we are placing altogether too much emphasis on the theoretical considerations, and that we must come back to common-sense ideas and realize that in a compression member we want a good sturdy member, a member all of whose parts will work together, and not a highly theoretical member where the metal is in thin sections widely spread.

I spoke of the building ordinance and my hope that it would be changed to allow the use of I-beam columns in buildings. If such a change were made I would also suggest that the wording of the limiting length of cast-iron columns be changed. At present it reads: "The limiting length of a cast-iron compression member shall not be more than 70 times the least radius of gyration." The average layman and the person who has many other things to think about does not want to figure out the "70 times the least radius of gyration." The way that rule was obtained was this: They took the old rule of thumb of limitation of the length of a cast-iron column to 24 times its least diameter and translated it into 70 times the radius of gyration.

I do not know particularly what columns are referred to as freak columns. Sometimes we run across water-tanks carrying very heavy loads with supporting columns of single angle sections. Of course, theoretically that would seem to be all right, but it does not always look right. Outside of that I do not know of any particular instance just now.

Mr. Vanderlip: May I ask a question? Mr. Jensen remarked about the radius of gyration not having much to do with the strength; this made me think of the form of column that is used in a long boom—some of these modern long booms for derricks, 50 or 60 ft. long. They make those out of four angles, and near the ends where the blocks and pulleys are fixed they come down to possibly 8 in., back to back in both directions. Then as they go toward the center they bow them out so that they are perhaps 16 or 18 in. wide. Would that not seem to indicate that the radius of gyration is a very important thing in there? The farther out they bow, the larger becomes the radius of gyration to take care of the bending tendency of the column.

Mr. Jensen: The point I wanted to bring out is that theoretical considerations lay large stress on the radius of gyration, but actual tests show it does not make any difference, as is shown at the Watertown arsenal—I am referring to this in particular. They took a certain type of column, and varied the ratio of $\frac{l}{r}$ from 25 to 175, and they found, so far as the load-carrying capacity of the column was concerned, that the ratio of $\frac{l}{r}$ seemed to make no difference; a long column would carry just as much as a short one. Some recent tests at the University of Illinois indicate that this radius of gyration —a thing that has troubled us ever since our student days—really has no right to trouble us. It has not much to do with the strength of the column. We have to make some allowance for it, in a way, but we should not lay as much stress on it as we do.

These tests also bring out another fact. According to the formulae for long columns, we ought to get the higher stress in the middle of the column. When the column is tested, that highest stress is not necessarily at the middle. It may be there or somewhere else.

I do not wish to discredit theoretical considerations, by any means, but to me it is more important to be guided in all these things by actual tests, and if these tests show that the radius of gyration has not much to do with the strength, we ought to throw overboard the radius of gyration.

Mr. Davidson: Mr. Jensen brought out one point that has troubled me somewhat, and that is how to make rigid connection between a floor beam and a Lally or Acme column. He also brought

out in his remarks the advisability of using the I-beam. With an I-beam with floor beams riveted to it, there is rigidity to a building. In the other case there is a little steel or iron pipe filled with concrete, set up on a little cap, with no rigidity to it at all.

H. J. Burt, M. W. S. E.: With reference to using I-beams for columns and also other light members, where the load is small in comparison to the section that is required on account of the rule limiting the value of $\frac{l}{r}$, I have resorted to this expedient: I have figured the radius of gyration of only the outstanding metal; that is, the flange of the I-beam. That permits one to go to a longer length for a good sized member and seems to me to be altogether permissible, provided there is enough metal in the flange to carry the load specified.

W. L. Cowles, M. W. S. E.: It seems there can be no question about the cylindrical section. Probably the strongest—it must be the strongest—is the pipe section, and evidently such a form of section has been used for building construction recently, but I should imagine that it might be quite difficult to make satisfactory connections. I am not familiar with the dimensions and what the connections may be. I recall that pipe sections—in fact, actual gas pipes—were used quite extensively by the Brown Hoisting Machinery Co. some years ago. The sections were prepared by putting them in the blacksmith shop and straightening out or flattening the ends. They were used in a riveted connection, and for compression members so far as they were available; also for the posts of bridges —the chords, however, being made of channels—and for lateral struts.

I have never seen this method of construction used anywhere else, and in many places it might be considered a difficult or uneconomical one as to shop work, but the Brown company was equipped for that kind of work, and the results seemed to be very good. The pipe section certainly proved economical in construction and served the purpose very well.

I do not know whether the Brown company is still using that section or not, but if these pipes can be utilized economically they will naturally make the best section for the purpose.

Mr. Horton: It seems to me that the necessary thing to do in this matter of light column work is to take off the limitation as to radii length of the member. If there is any reason why the limitation should be 120, it has not been disclosed—only the mere fact that it happens there. The tests show 200 radii lengths doing just as good work essentially as 100. For many years I have said that a circular column, if we could make the connection rigid, is the ideal thing as far as cost and everything else is concerned, the difficulty being in the connections.

C. S. Pillsbury, JUN. W. S. E.: Two small channels make a good section for light horizontal struts with no particular load, such as struts in water towers. In such a member the channels have their webs vertical and are laced horizontally. This design seems to work out very well as regards connections and is a fairly stiff and economical section. I have also seen the box shape, made of four angles with lacing on the four sides, used for very long horizontal struts. The difficulties with this last section seem to be that the lacing is too large a portion of the total weight of the section and that the shop work cost runs up considerably.

The fact brought out in regard to large columns—that they failed by wrinkling and not by flexure—is a most important point which is not always given the consideration that it merits. If composite members fail by wrinkling of the parts at 65% of the load that a pipe or **H** section will stand, then 35% of the maximum efficiency is lost. By spacing the rivets closer or by changing the proportion of the different parts, it may be possible to make built-up members approach nearer the strength of a solid section of equivalent area. Mr. Horton suggests that a large number of tests be made of small-sized members with variations in the relative sizes of the flange and web elements, and in the numbers and sizes of rivets. It might then be possible, from the results obtained, to recover some of the 35% lost efficiency.

Olin H. Basquin, M. W. S. E.: In regard to pipe sections, I recollect that tests were made at the Watertown arsenal not long ago, perhaps within three or four years, in which Mr. Howard showed that pipe sections of moderate lengths fail practically always at their elastic limits when tested as columns. He also showed the same thing for these **H** sections, the form used by the Bethlehem Steel Company. These sections were used with square ends and were loaded very carefully. One would not expect to get such a result in actual practice because they could not be loaded as carefully in a structure as they were in the laboratory. That is one difficulty with all tests that have been made on columns, because the load which the column will stand depends very largely upon the care used in loading it, and the degree of accuracy used in getting that load at the center of the column section.

The theory of columns is generally thought to be in a very unsatisfactory condition, but this is due to the fact that people do not pay attention to the theory that is already fairly well developed. About thirty years ago Professor S. W. Robinson, of the Ohio State University, published a paper on the strength of wrought iron bridge members, and that paper has been republished in No. 60 of Van Nostrand's Science Series. In that he gives the correct formula for maximum stress in a column, which is based on the same assumptions that are ordinarily used in the beam theory. This formula was rediscovered by Professor Marston, now of the Iowa State

College, then a student at the University of Wisconsin, and was published in the *Proceedings of the American Society of Civil Engineers,* in connection with a paper by Dean Johnson, but Dean Johnson warned the public that this was a very dangerous theory to use in practice—for just what reason I do not know. This theory has crept into the German text-books and has been used there for a long time, but you will find it in a rather subordinate position in the better American text-books of the present time.

This theory depends upon the load on the column being a little out of center; that is to say, it is the theory of eccentrically loaded columns and it is the true theory for ordinary columns; but in order to apply it, we must know where the load is; in the ordinary column, of course, we do not know where the load is; it may be an inch out from the axis of the column; so, in using an ordinary column formula, we are guessing how far the load is from the center of the column. Of course, that is a short way and a convenient way of estimating columns in practice, but I want to call attention particularly to the fact that the theory of columns, in so far as columns are well built, is not on a particularly unsatisfactory basis. This theory was taken up by Professor Tetmyer, who published a book on columns and made a great many experiments on eccentrically-loaded columns of rather small size. He took, particularly, a couple of angles, fastened together, and loaded one of the legs, and found that the deflection and failing load corresponded closely with the values which one gets from calculation.

Three or four years ago—perhaps a little longer—Mr. Buchanan published a series of tests made for one of the eastern railways—I think it was the "Panhandle." In some of those tests, which were made on the top chords of bridges loaded on the pins with a certain eccentricity, the deflections which he gives will be found to correspond almost identically with those calculated, but those columns did not fail at the maximum stress which was calculated. Why? Nearly all of them, I think all of them, failed in the details, particularly at the end plates; and I think that is true of nearly all tests of full sized columns made up of riveted shapes. They do not fail at the maximum stress figure, but they fail in the details.

What is needed is more experiments like those recently performed at the University of Illinois, in which they were testing the strength of riveted joints. As far as the columns are concerned, it does not seem to me that there is much need of testing a great many columns in the laboratory until we know how to make the details properly, and then it is not at all certain that the tests will be of any great value, because the failure of a column depends upon how carefully it is fabricated and just how the load is applied, and to apply the load very carefully in any one position in practice is almost impossible. We cannot duplicate in practice the conditions

of the laboratory, so that the results which are obtained in the laboratory will not correspond to those obtained in practice.

Mr. Horton: I am disposed to suggest that the difficulty with the details was that they wrinkled, and have suggested that a thousand tests be made in the laboratory to discover how to lessen the wrinkling.

Chas. K. Mohler, M. W. S. E.: I wish to call attention to some points which may be of interest, in connection with the distortion and partial failure of some trestle columns under conditions where they should not have failed, if the bent, of which they formed a part, had been properly designed. The distortion was made possible on account of the omission of diagonal bracing between the columns. Briefly, the bent was located at an angle in the north ap-

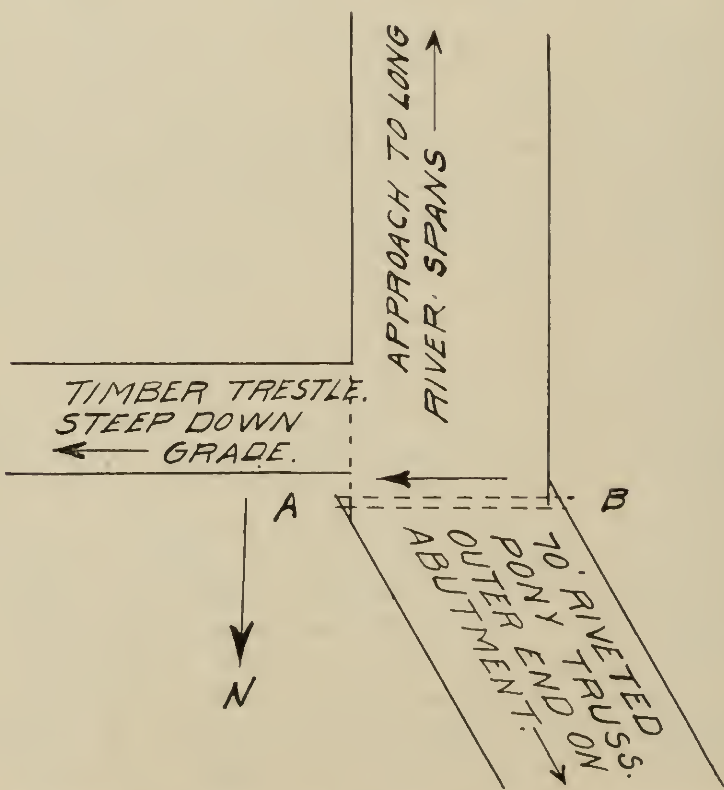

Fig. 1. Plan of Bridge. "A B" Bent with Distorted Columns.

proach to a bridge over the Monongahela River at Pittsburgh. The columns carried the east end of the riveted pony truss, which made an angle of about 35° or 40° at this point with the main approach. As shown in Fig. 1, a timber trestle was built at right angles in the opposite direction. Through expansion and contraction, or the tilting of the bents of the timber trestle, or both, the spans, together with the tops of the columns, were carried in the direction shown by the arrow. The columns were fixed at both ends, and as a result

both columns were bent in double flexure or reverse curves as shown in Fig. 2. The lacing bars in compression were badly buckled. The columns were not over 20 ft. high. There would have

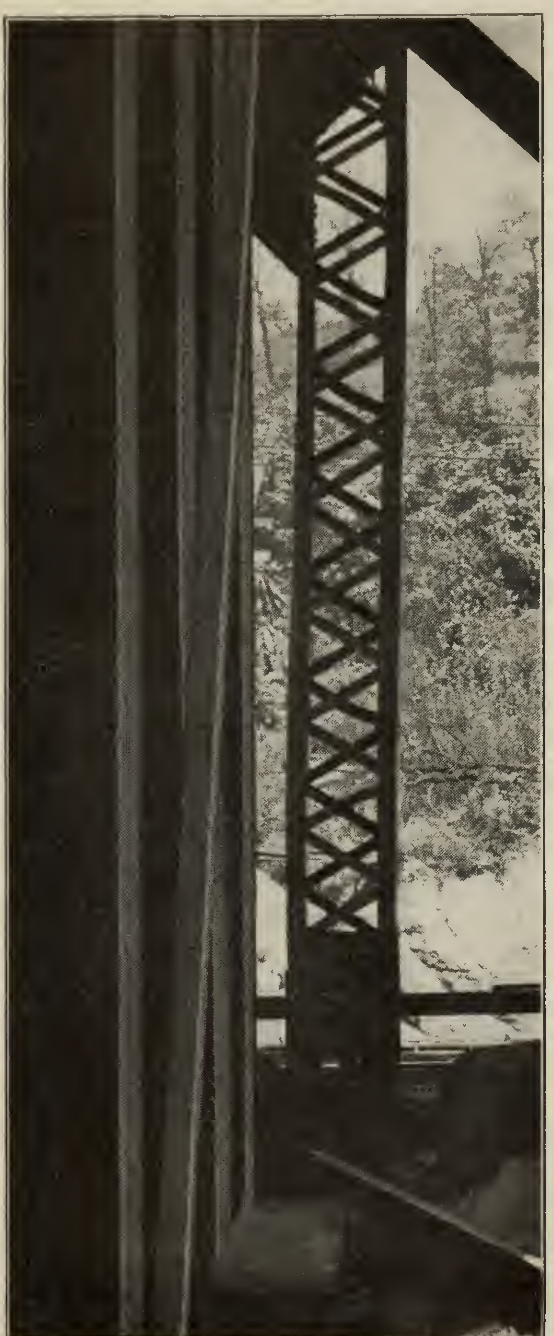

Fig. 2. Showing Double Flexure of Column.

been no failure from any strain that comes upon the bent if it had been supplied with the necessary diagonal bracing. The omission of the diagonals was inexcusably bad design. There were many

other instances of bad detail in this particular structure, but they do not relate to this discussion.

This simply shows that many times failure of a structure is caused by some of the members having to take care of loads and stresses which they were not designed to carry.

F. G. Vent, M. W. S. E.: Mr. Jensen made a remark about not worrying too much over the proportion of the length to the radius of gyration. I think when you get over 200 you have to begin to look out. A short time ago a certain manufacturer submitted a design for a roof truss, which I had occasion to check. It was what is called a skimp design, and in figuring it over I found that the sections had a large ratio of $\frac{l}{r}$. One of his excuses for this was that we had a structure which was built where the $\frac{l}{r}$ was somewhere around 400; built by George S. Morison. In referring to the plans for that truss I found that by taking the section of the compression member and figuring only the outstanding metal in the section, one could reduce the $\frac{l}{r}$ to about 150 to 175, and the design was well proportioned. The design that this manufacturer was offering was somewhere around 200 $\frac{l}{r}$ in every member. This shows that if we figure in all the metal we will sometimes find that the $\frac{l}{r}$ is over 300, and if we figure just the outstanding flange we will have a structure in which the $\frac{l}{r}$ is low.

Mr. Horton: I understand, Mr. Jensen, that the $\frac{l}{r}$ is of much less significance than is frequently ascribed to it, and the tests of full-sized members certainly show this fact. Tests have been made, up to 175 $\frac{l}{r}$ on large pipe and **H** sections, and the ability to stand loads is not much lessened at that length (about 20% less than the strength at 35 $\frac{l}{r}$). No column of over 120 $\frac{l}{r}$ can be used in Chicago, whereas tests of rolled sections show a loss of only about

16% between $35 \frac{l}{r}$ and $120 \frac{l}{r}$. With the straight line formula, $16{,}000—70 \frac{l}{r}$, to limit the radii length is absurd.

Lewis McDonald: There has been considerable talk about the relation of the radius of gyration to the length, and because some experiments have seemed to show that this did not have the significance which we have usually attributed to it, it seems that some would do away with it altogether in their designs. I do not think that we should forget our early training in this respect and we should still consider the relation of the radius of gyration to the length. But there are other things which enter into the design of a column which perhaps we have overlooked in the past and which recent failures have brought more particularly to our attention, and while we should not omit to take this into consideration, we should give other things, such as wrinkling, thickness of material, etc., their proper consideration. I do not think it is the intention of any one to say that we should design our columns up to 300 or $400 \frac{l}{r}$. Probably the original formula which was worked out was all right, and so long as we had homogeneous material, that probably would be the only consideration which we would need to give. But in built-up members it certainly is necessary that we consider the shop work and the effect of driving more or less rivets and other things which we have heard discussed.

Mr. Horton: Referring to Mr. Vanderlip's remarks, we can scarcely imagine a boom built of four angles which would not be very satisfactory as regards $\frac{l}{r}$. I am reminded of a boom 100 ft. long, 24 in. square in the center, built of four 1½ by 1½ by ¼-in. angles, laced on four sides with 1¼ by 1¼ by 3/16-in. angles in 2 ft. panels. This boom was entirely satisfactory as regards $\frac{l}{r}$, but the other question came up as to its sufficiency as a beam. Could it be handled as a beam, that is lifted at the center or at the ends? Calculations showed that it could. Experiments made later showed that the actual corresponded with the calculated deflections. This is interesting, as a ratio of length to depth of 50 to 1 is an unusual proportion.

J. W. Bradford, M. W. S. E.: It is quite a problem to know just how light we can make many of these struts, but we are called on

at times to furnish some which are not so light. I know of instances where we have been called on to make struts 2 ft. or more in width, and laced with angles, which makes a very heavy and costly member. The ordinary strut made with four angles laced makes a very good strut but it runs up in weight, and where the four angles are turned in and laced, the cost of shop work is very great. In many cases the strut made of two channels with lacing between them makes a very light strut and one with which it is very easy to get a good end connection.

Arthur N. Talbot, M. W. S. E. (by letter): The compression member is a fruitful topic for discussion, and the remarks made on this topic are interesting and bring out many different views. As the column is used under such diverse conditions, it is not strange that such a variety of views exists. Our knowledge of the action of the column is incomplete, so much so that its properties offer a very promising field for investigation. In fact, one of the great needs in the line of structural engineering lies in experimentation on the action of compression members. However, it should not be lost sight of that a great deal of information on column action is available and that certain things have been established. A reader might gain wrong impressions from some of the statements in the discussion, impressions which the speakers doubtless did not intend to convey. Possibly a few general statements will serve to clear up some ambiguities.

(a) Long columns do fail by flexure, very much as indicated by Euler's analysis. Simple laboratory experiments show this. A very good collection of the results of the tests which have been made on columns may be found in the *Proceedings of the American Society of Civil Engineers* for December, 1911, pages 1290-98, and these tests bring out very well the effect of flexural action in long columns. If the modulus of elasticity of the column is known, and the section is such that the column will not collapse or distort laterally, the maximum load which will be carried by very long columns may be fairly definitely stated if the end condition of the column is known. For mild steel, long column action may be expected in columns having a length, say, of more than $125 \frac{l}{r}$ for columns with round ends, and of more than $250 \frac{l}{r}$ for columns with fixed ends. However, it is known that the stiffness of the built-up column is much less than that of a solid section, as is shown by tests in flexure, and therefore a lower value of the modulus of elasticity must be used in Euler's formula than will obtain for solid material.

(b) What constitutes a round end and what a fixed end cannot be stated very satisfactorily. It seems evident that a pin-ended

connection will offer little end restraint and may be considered to be a round-ended column in one plane. A flat-ended column may act as fixed-ended, especially if it has an enlarged base resting on a firm bearing. Between the extremes of round ends and fixed ends there is a wide range of conditions, and the method of holding the ends, the tightness of the riveting, and the fixedness of the supports are elements which give uncertainty. There is a lack of information on the actual end restraint to be found in building construction.

(c) For very short mild steel columns, of other than solid section, failure is generally by a crinkling or wrinkling action. This action starts at some point where the local stress exceeds the yield point, and this critical load should be considered the strength of the compression member, even though in some forms of section the ultimate load for columns of very short lengths may be such as to give an average stress well beyond the yield point of the material. Just how far this critical load is below the load which would give an average stress equal to the yield point of the material, will depend upon such matters as the imperfection of parts, like crookedness, eccentricity of bearing, eccentricity of rivet bearing, and the movements of the structural elements upon each other. For such short members the strength depends very much upon the form of section and the method of fabrication.

(d) For compression members having a length intermediate between that of the very long column and the very short compression member, the slenderness ratio $\left(\frac{l}{r}\right)$ does affect the strength of the column. Just why this is true is not clear. It is evident that the reasoning about the effect of the length used in the derivation of Rankine's formula is not entirely tenable. It might even be thought that as the column of intermediate length does not deflect laterally to an extent which will explain failure, the strength of a column will remain nearly constant from the very short column to the vicinity of Euler's curve. However, the tests of columns show a gradual reduction in strength with increase in length, though the reduction is of a different character and generally less in amount than that given by Rankine's formula. In fact, tests show that a straight line inclined to the axis represents the results of tests of compression members of intermediate length very well—better than the Rankine formula. Failure in such columns may be by crinkling or wrinkling, the yield point being exceeded at places not necessarily at the center of the length, and no special bowing or lateral deflection occurring in the amount which would be necessary to explain the failure, such as is seen in the failures of very long columns. In other words, failure seems to be due more to local causes than to general curvature along the whole length as is assumed in most column analyses. As has been indicated, reduction in strength in this intermediate field may

be said to be directly proportional to the length of the column, though just why this is has not been determined.

(e) The extent to which length affects the strength, for columns of this intermediate length, seems to depend upon the shape of the section, the thickness of parts, and the method of making up the section, as whether the structural elements are riveted together, as in the case of built-up columns, or whether the piece is an integral rolled section. The tests of rolled **H** -sections made at Watertown arsenal (referred to in this discussion) may be expressed by the formula $\frac{P}{A} = 33{,}500 - 60\frac{l}{r}$ for ultimate strength, up to the limit of the tests, $\frac{l}{r} = 150$, and of $\frac{P}{A} = 30{,}000 - 50\frac{l}{r}$ for the elastic limit of the columns. The tests of lap welded steel tubing may be expressed by the formula $\frac{P}{A} = 36{,}000 - 65\frac{l}{r}$ for ultimate strength, for lengths up to the limit of the tests, $\frac{l}{r} = 175$, and for the elastic limit strength by $\frac{P}{A} = 32{,}000 - 50\frac{l}{r}$. These equations for elastic limit strength are applicable for lengths up to the longest length tested. The equations for ultimate strength do not apply to tests of columns having a length of $\frac{l}{r} = 25$ or less, for here there is insufficient length to complete the wrinkling action. Tests of the Gray type of column (with limits up to $\frac{l}{r} = 60$) made at the University of Illinois are expressed by the equation $\frac{P}{A} = 36{,}500 - 155\frac{l}{r}$. It is evident that in this form of column, length has a much larger effect than in the two other forms. The general forms of column sections may be expected to have strength equations lying between this equation and the preceding two. An interesting fact brought out in the tests of the Gray columns (see Bulletin No. 56 of the Illinois Engineering Experiment Station) is that at small deformations the effect of length of column is very much less than at the higher deformations, and in this may be found a suggestion

bearing upon the explanation of column action. It should also be noted here that in tests of built-up columns the load-deformation diagrams have a considerable curvature even at low loads, while in the tests of the rolled columns the low load-deformation diagram is nearly straight up to the yield point of the columns.

(f) The amount of the effect of the slenderness ratio $(\frac{l}{r})$ through this range of intermediate lengths depends also upon the end condition of the column. The equations given in the preceding paragraph are for columns tested with flat ends which acted in the tests as fixed ends. The diagrams giving the results of tests of free-ended columns show a greater slope. Just what explanation best fits the existence of this greater slope, if general flexure is not the only cause of decrease of strength, cannot now be told. It must be understood, however, that end condition does affect the strength reduction for columns of intermediate length, and that a statement of the end condition assumed may well go with the formula.

It may be observed, too, that a single formula for all forms of sections and for different end conditions may not be expected to express the actual column strength.

Some very interesting questions have been raised in the discussion on compression members. One of these is, why not remove the limit of $\frac{l}{r}$? Why was this limit inserted in the ordinance? Possibly because it was felt that there is too much uncertainty in the action of the column beyond the length of $120 \frac{l}{r}$. Possibly it was done because it was appreciated that the end condition—whether round or fixed—so largely affects the strength of very long columns, and it was not expected that the brief statement in the ordinance could provide for the variations in condition likely to be found in practice. Besides, it has been thought possible by some that in a column formula for homogeneous columns the line which represents the strengths of columns of intermediate length may intersect Euler's curve instead of being tangent to it as commonly assumed.

Enough has been said to justify the remark that more experimental knowledge of column action is needed, for the variety of condition of section, of bearing, of length, and of connections. The view expressed by Mr. Horton, that a large number of laboratory tests are essential to give us an adequate understanding of column strength, has much to support it. The effect of form of section, of thinness of parts, of local crookedness, of end condition, of length and slenderness ratio for different end conditions and different forms of section, of form of lacing and its spacing, of lateral stiff-

ness, of the effect of local overstress, of the effect of the rivet holes and of filling the holes with rivets, of the influence of slip of rivet—it would be easy to overrun Mr. Horton's 1,000 tests. As Mr. Horton says, "No mere mental analysis will ever show us the required relations. Physical tests are required."

And why may not such tests be made? Not all that may be suggested, but a large number along specified lines selected with a view of advancing knowledge on many disputed and unsettled questions. And why should not the Bridge and Structural Section of the Western Society of Engineers take an active part in promoting a movement for such experimental work, in outlining the most profitable lines of research, and in other ways contributing toward the advancement of knowledge in this important matter? Surely a means of cooperation in so promising and fruitful a field may be found.

NOTES ON PRODUCER GAS POWER

H. F. Smith.*

Presented before a Joint Meeting of the Electrical Section, W. S. E., and the Chicago Section A. I. E. E., March 25, 1912.

The most fundamental chemical reaction in a gas producer is the combination of carbon and oxygen to form the two oxides of carbon, namely, CO and CO_2. It seems to be established with a fair degree of certainty that these oxides of carbon are produced in the order named. Incandescent carbon being brought into contact with oxygen combinés with it to form the single oxide of carbon, CO. It may, therefore, with propriety be called the primary oxide. On being mixed with additional oxygen this primary oxide is further oxidized to CO_2. Both of these reactions are reversible. Under suitable conditions CO_2 will surrender one oxygen atom with the formation of CO, while under different conditions CO will combine with one oxygen atom to form CO_2. The same is true to a limited degree of the primary oxide of carbon—CO. Under suitable conditions oxygen will combine with carbon to form CO. Under other conditions CO will split up, liberating oxygen and free carbon. It has been pointed out recently that with reversible reactions of this character the conditions determining the direction of the reactions may overlap, and, in fact, frequently do overlap so that we can have existing at the same time conditions causing the decomposition of CO_2 by carbon, whereby CO is formed and conditions in which CO will take up additional oxygen with a resulting formation of CO_2. In fact, it seems that both these reactions occur simultaneously in practically all conditions that are met with in producer operation. The extent to which one reaction predominates is determined by conditions. For any given set of conditions, a state of equilibrium will finally be attained, in which the rate of production of CO from CO_2 is exactly equal to the rate of production of CO_2 from CO, so that no change in the relative proportions of these constituents will occur, no matter how long the conditions are maintained without change. The conditions governing the rate at which these reactions occur in a gas producer are the same as those governing the rate of chemical reaction in general.

First: The rate of reaction as well as the direction of reaction and the final condition of equilibrium depend largely on temperature.

Second: The rate of reaction is determined by the degree of molecular contact between the reacting bodies, or, in other words, by the extent of surface exposed to the reaction.

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*Gen. Mgr. The Smith Gas Producer Co., Lexington, Ohio.

Third: The extent to which the reaction proceeds will be determined by the time of contact, so long as this time of contact is shorter than that required to obtain complete equilibrium where the reactions concerned are reversible. Since the time available for the reactions occurring in a gas producer is nearly always less than that required for the attainment of complete saturation equilibrium, this element of time of contact becomes one of considerable practical importance.

To illustrate briefly, these three fundamental principles are concerned in practical operation of gas producers, as follows:

First: The rate of gasification of fixed carbon rises with increase in temperature. The equilibrium ratio of CO to CO_2 also rises with increase in temperature. This means that high fuel bed temperatures permit a rapid rate of gasification, and also permit the production of gas with a high content of CO and a relatively low

Fig. 1. Typical Down-draft Producer Plant for Texas Lignite.

content of CO_2. Conversely, with a low fuel bed temperature it is impossible to secure high rates of gasification of fixed carbon, and it is likewise impossible to secure a high ratio of CO to CO_2. In other words, with low producer bed temperature the percentage of CO_2 in the gas is bound to rise and that of CO is bound to fall, other conditions being equal.

Second: The rate of gasification of fixed carbon is determined in no small measure by the total area of contact between the carbon and oxygen. Obviously, chemical union between two substances can take place only at their surfaces of contact. With a given degree of molecular activity, as evidenced by the temperature, a certain definite rate of combination per unit area of surface will occur.

From this it is clear that the rate of gasification of fixed carbon will be increased by increasing the surface of carbon exposed to the blast. It is on this account that some of the producer fuels, such as charcoal, can be gasified more rapidly and attain to the normal state of equilibrium between CO and CO_2 for a given temperature more quickly than is the case with dense, non-porous fuels such as anthracite. Obviously also, the size of pieces of fuel constituting the fuel bed will have a marked influence on the surface exposed. If no other element than this were considered, the smaller the particles of fuel the greater would be the surface exposed in a given cubical space, and one would expect a more rapid gasification of finely divided fuels than of coarse fuels. With very fine pieces, however, the access of gas to the surface of the fuel is obstructed owing to the fact that the small particles lie much more closely together. In a practical way this is very intimately related with the third element, namely, time of contact.

Chemical reactions are by no means instantaneous, and under a given condition of temperature considerable time is required for the attainment of the condition of equilibrium between CO and CO_2. To give a concrete idea of the time actually required under given conditions for attainment of equilibrium, we quote from the recent investigation by the United States Bureau of Mines, as follows:

"At temperature of 900 deg. Centigrade, time of contact required to attain practical equilibrium, 142 seconds.

"At 1000 deg. Centigrade, time of contact required to attain practical equilibrium, 123 seconds.

"At 1100 deg. Centigrade, time of contact required to attain practical equilibrium, 90 seconds.

"At 1200 deg. Centigrade, time of contact required to attain practical equilibrium, 18.9 seconds.

"At 1300 deg. Centigrade, time of contact required to attain practical equilibrium 8.8 seconds."

These rates are observed for charcoal, which is very porous and has a largely extended surface. For anthracite at a temperature of 1100 deg. Centigrade, 34 seconds of contact were required to reach the same degree of saturation as is attained in 30 seconds with charcoal. At 1200 deg. Centigrade, 47 seconds are required for anthracite as compared with 19 for charcoal. At 1300 deg. Centigrade, 12 seconds are required for anthracite to attain the same degree of saturation attained in 9 seconds with charcoal. This would seem to indicate clearly the influence of extended surface on the rate of oxidation of carbon, and more particularly on the time required to reach the highest possible ratio of CO to CO_2 for the temperature. These principles are of the utmost importance in connection with the practical design and operation of producers.

So far we have considered only gasification of fixed carbon. In the operation of producers on anthracite, coke and the like, this

is the chief reaction. In connection with this, however, must be mentioned the decomposition of water vapor, which is made use of to bring about higher producer efficiency by utilizing the surplus heat of the initial combustion of carbon to CO, and by the endothermic quality of the reaction to reduce the temperature of the fuel bed. While many other methods of controlling fuel bed temperature have been suggested, none has met with the universal ac-

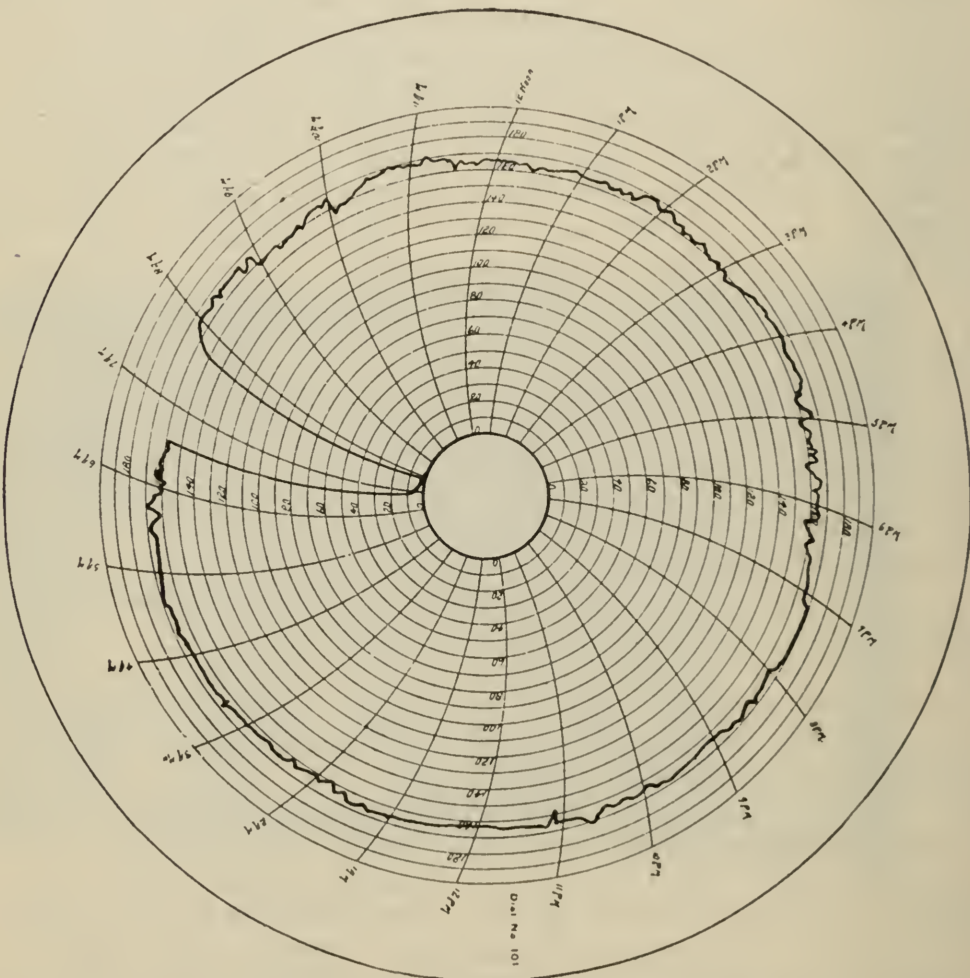

Fig. 2. Continuous Calorimeter Record from Plant Operating on Texas Lignite, illustrated in Fig. 1.

ceptance and adoption characterized by the use of steam. That there is ample reason for this might be suspected from the rather intimate relation between carbon and hydrogen in a chemical way. Not only is water vapor decomposed by hot carbon into carbon monoxide and hydrogen, but it has been recently discovered that the presence of hydrogen in some form is absolutely essential for the further combustion of the carbon monoxide. Perfectly pure carbon monoxide gas will not burn in perfectly pure oxygen. The

presence of hydrogen in some form seems to be essential to bring about the combustion of the carbon monoxide to carbon dioxide. If a jet of perfectly dry hydrogen-free carbon monoxide gas is lighted in air it will burn freely provided the air contains moisture. If, however, the burning jet is brought into contact with perfectly dry air it is immediately extinguished. The chemistry of hydrogen and carbon are still more intimately associated in that compounds are formed of these two elements in almost any proportions. Carbon will combine directly with hydrogen under suitable conditions with a production of methane, and all of the ordinary fuels contain considerable quantities of hydrogen and carbon in combined form. The chemistry of these hydrocarbon compounds is a subject that is but imperfectly understood. It is a matter, however, of the highest importance to the producer-gas engineer, particularly where fuels containing a considerable quantity of hydrogen and carbon in combination are to be gasified. Aside from its property of promoting the combustion of carbon monoxide, and of combining in all proportions with carbon, hydrogen has another important property of material interest to the producer industry, particularly as it relates to the application of producer gas to gas engines. This property is its enormous rate of flame propagation, and has often been confused with ease of ignition. It has been frequently stated that hydrogen is a potent cause of prematuring and backfiring on account of the fact that it is more readily ignited than the other constituents of producer gas. This, however, has little foundation in fact. Hydrogen will not ignite at materially lower temperatures than carbon monoxide or methane, but having once been ignited the rate at which the flame is propagated by hydrogen is enormously greater than the rate of flame propagation in any other combustible gas. Carefully conducted experiments on this subject show that under favorable conditions the rate of flame propagation in explosive mixtures of hydrogen and oxygen will reach the rather startling figure of 2,000 ft. per sec. It is largely on account of this property of increasing the rate of flame propagation in mixtures containing hydrogen, that it is so highly important to control accurately the percentage of free hydrogen contained in producer gas. The entire elimination of hydrogen is not only impossible but most undesirable, but if the rate of explosion is to be maintained anywhere near constant the percentage of hydrogen in the mixture must be controlled with considerable accuracy.

Some few items in connection with the chemistry of the hydrocarbon compounds is of interest in the manufacture of producer gas. The composition of these bodies may be altered simply by the application of heat, in which case the compounds are split into two portions, one of which is less complex and the other more complex in composition than the original compound. These bodies may also be reduced by combustion with oxygen, and while there are many

evidences that selective combustion—that is to say, the combustion of hydrogen in preference to carbon in a limited air supply—does not occur, nevertheless, there are conditions arising in which the total results of reaction are the same as though this selective combustion did exist. Accordingly, when hydrocarbon vapors are burned

Fig. 3. Up-draft Gas Producer for Bituminous Coal with Motor-driven Tar Extractor.

in the presence of a limited air supply, the products of combustion usually consist of water vapor—carbon dioxide—and free carbon in the form of lamp-black or soot. These two properties are mentioned in connection with hydrocarbon compounds, for the reason that both

have been made use of to a considerable extent in an attempt to produce fixed gas from the various hydrocarbon compounds in coal.

The relation of these chemical principles to producer design is readily perceived. In the manufacture of producer gas there are three distinct steps.

First: The preparation of a suitable blast consisting of the various elements which it is desired to combine with the fuel.

Second: Bringing about a combination of the elements in the blast with the fuel to be gasified.

Third: Cooling and cleaning the gas to render the same suitable for use.

Fig. 4. 1000 H. P. Producer Plant Operating on Illinois Bituminous Coal, Alton, Ill.

In producer gas for power it is of the highest importance that the gas should have as nearly uniform composition as possible. As a first step toward the production of uniform gas, it is necessary that the blast supplied to the producer should be of uniform composition. In other words, a constant ratio must be maintained between the oxygen and water vapor in the blast. Without taking time to go into detail concerning the various methods that have been suggested for this purpose, it may be remarked that so far only one method seems to meet all requirements. It is a well-known principle in physics that air at a given temperature will take up a definite proportion of water vapor and no more. It will take up water

by evaporation until its point of saturation is reached, provided, of course, that it is kept in contact with a sufficient surface of water for a sufficient time for this saturation to occur. The temperature of saturated air, therefore, is a direct measure of the amount of moisture contained in it, and if we supply to the producer saturated air at a constant temperature, we will supply a blast containing a definite and constant proportion of moisture. This method of vapor control is the only one that compensates fully for the normal daily and seasonal variations in atmospheric moisture. All mechanical

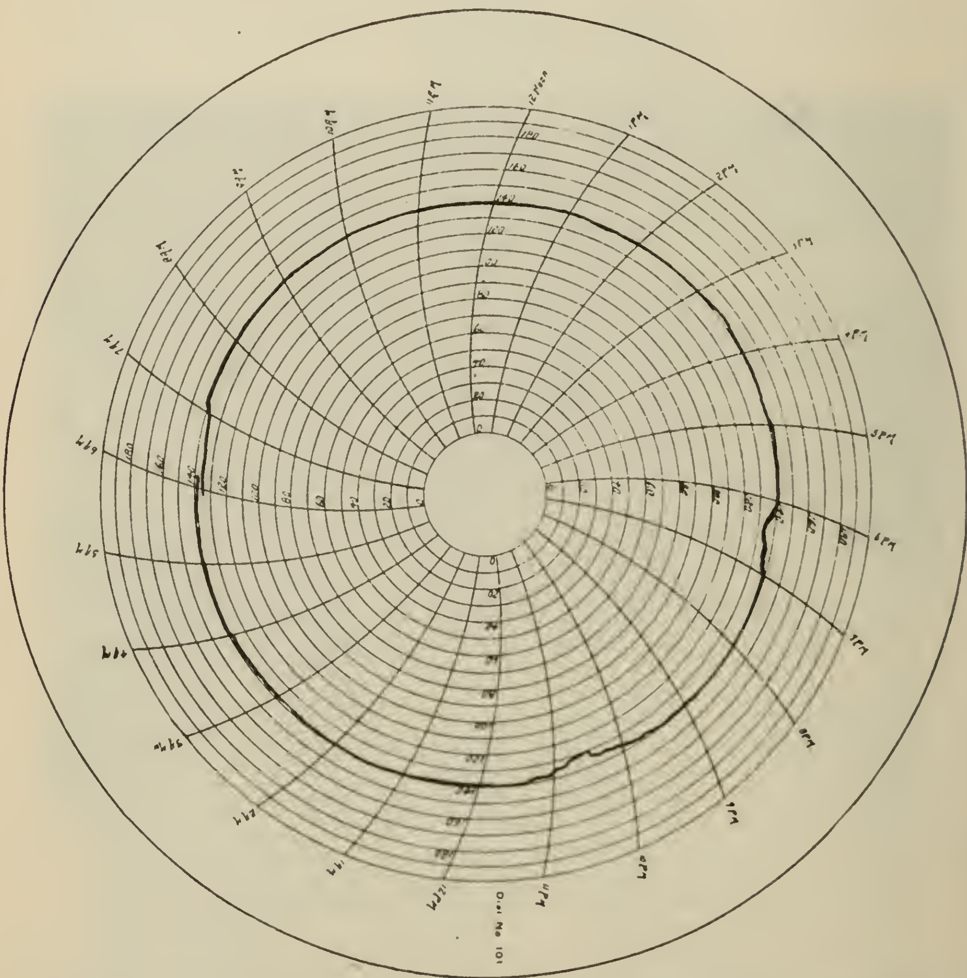

Fig. 5. Calorimeter Record from Plant illustrated in Fig. 4, Illinois Bituminous Coal.

appliances for measuring off a definite amount of water to be evaporated into steam are defective in that however perfect they may be intrinsically, they cannot possibly compensate for variation in the moisture content of the air supplied to the conditioning apparatus. The air for the blast can be readily heated and conditioned with regard to moisture by bringing it into contact with an extended surface of hot water. In this way there is no direct

introduction of vapor into the blast. The water, of course, must be below boiling and the evaporation will never be more than sufficient to saturate the air at the temperature at which it leaves contact with the water. The condition with respect to moisture of air saturated in this manner can be readily determined by noting its temperature. It is of course important to have the conditioning apparatus designed so that no water spray will be carried forward mechanically in the blast, but where hot water is used for conditioning, this is not at all difficult. Steam cannot be satisfactorily employed for this purpose for the reason that it is not practically possible to maintain an absolutely constant condition of steam, and any variation in the condition of the steam will result in a corresponding variation in the actual degree of saturation without necessarily changing the temperature of the blast. The writer has frequently observed that there is a material difference in the percentage of moisture carried forward in a blast saturated to a given temperature by hot water, and a blast raised to the same temperature by the admixture of steam. It would seem likely that this is due in no small measure to the fact that where steam is used to saturate the blast, not only is moisture carried into the blast in liquid form with the steam, but a portion of the steam is condensed to provide the necessary heat for raising the temperature of the air, and these various small particles of liquid water are carried forward mechanically into the fuel bed. As a rule, therefore, a blast saturated to a given temperature with steam will carry more moisture than a blast saturated to the same temperature by the hot-water process. The method of saturation by contact with hot water has a further advantage in that it is favorable to automatic control. On suddenly varying loads the thermal inertia of the entire apparatus tends to prevent a change in saturation conditions, since this would involve a change in temperature, and this would be automatically resisted by all warm parts of the apparatus which would surrender heat rapidly to prevent such a change. It is a relatively simple matter also to provide automatic control by means of a thermostat located to register the temperature of the blast leaving the conditioning apparatus, and to regulate the supply of hot water as may be required to maintain this temperature constant.

In bringing about the combination of the various elements of the blast with the fuel in the producer, many items demand consideration. We have noted above that the conditions determining the rate of producer reactions are, (a) temperature; (b) surface of contact between the blast and fuel; (c) time of contact between the blast and fuel. The temperature at which the fuel bed may be maintained for continuous operation is determined by the fusing point of the ash contained in the fuel. Unfortunately, most American coals have ash that is fusible at a relatively low temperature. The temperature at which the producer may be operated being thus

strictly limited by the nature of the fuel, the lack of fuel bed temperature must be compensated for by increasing both the surface of contact between the blast and the fuel and the time required for the blast to pass through the fuel bed. These requirements demand the construction of a producer not only of greater sectional area but of greater depth than would be required for a fuel that would permit the use of higher temperatures. A brief consideration will show that the size of fuel fired to the producer has considerable influence both on the surface of contact and time of contact between the blast and fuel. If we assume a producer of given sectional area the time required for the blast to pass through a given depth of fuel would be directly proportional to the total area of voids

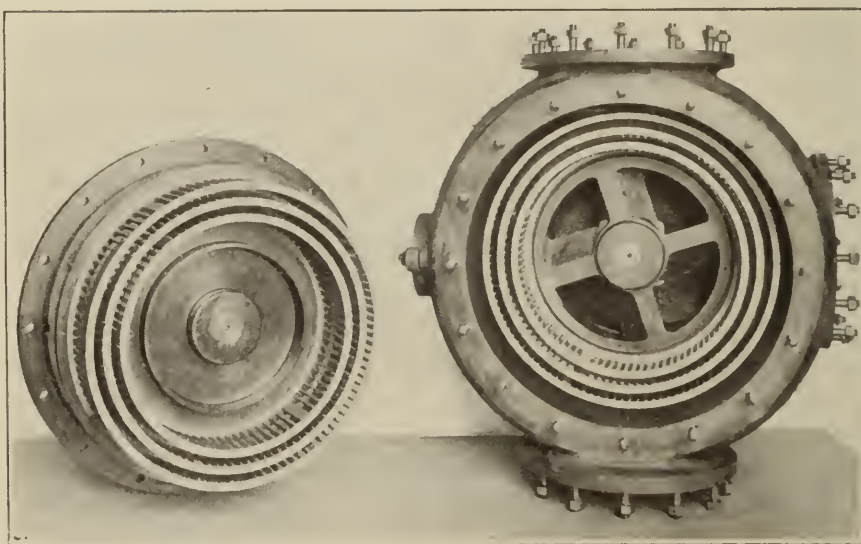

Fig. 6. Mechanical Tar Extractor.

in the fuel bed. The larger the pieces of fuel the greater the percentage of voids, and consequently the slower the rate of blast passage through the bed. On the other hand, the smaller the pieces of fuel the greater would be the ratio of surface to mass and consequently the greater would be the surface exposed to the action of the blast. We have, therefore, with regard to size of fuel, two variables, the resultant of which we would expect to reach a maximum for some particular size neither the largest nor smallest. This, indeed, is found to be the case. With anthracite, for example, the maximum capacity for a given depth and sectional area of producer is obtained with coal that will grade through $\frac{7}{8}$ in. and over $\frac{3}{16}$ in. square mesh screen. This coal is ordinarily marketed as pea. Larger sizes of anthracite, while permitting a slower rate of gas passage and a longer time of contact, present a surface so much reduced in total area that the capacity of the machine suffers distinctly. On the other hand, small fuel, while presenting an enormous

surface, so completely occupies the voids that the gas velocity through the relative small area remaining is so high that the time of contact is insufficient and the producer capacity is accordingly reduced.

In the actual design of the generator chamber it is important not only to proportion the diameter of the producer and depth of fuel bed properly in relation to the fuel to be used, but it is also very necessary to take some steps to insure a uniform distribution of blast over the entire sectional area of the producer. Since temperature is the limiting factor, if any portion of the fuel bed is driven at a more rapid rate than normal this portion must necessarily reach a higher temperature, and may even exceed the permissible temperature for the particular coal used, and cause fusion of the ash and clinkering. The principal difficulty in securing blast distribution is in preventing too rapid driving next to the producer lining. There is always a tendency for the fuel bed to be more porous and open next to the lining than elsewhere, and if the bed is simply maintained on a flat grate with a fuel bed of uniform depth discharging into a gas space extending over the whole upper surface of the producer section, the temperature next to the lining will be much higher than in the center of the fuel bed. It is accordingly very desirable to arrange the fuel bed so that the resistance next to the lining will be augmented. In the ordinary water bottom type of producer this is frequently accomplished by locating the air inlet in the center of the fuel bed, discharging the blast into the fire through a central tuyere, so that to reach the lining it is necessary to pass horizontally through a considerable depth of fuel. This would be a highly desirable method were it not for the fact that the concentration of the blast has a tendency to increase the rate of combustion in the immediate neighborhood of the tuyere, thereby raising the temperature at this point and introducing clinker trouble. Since the highest temperature attained in the fuel bed is usually at or near the point at which the air first enters the fire, it is plain that for uniform low-temperature conditions the grates should have as large surface as possible. This condition can easily be met and the low resistance of the fuel bed next to the lining compensated for by increasing the depth of fuel next to the lining, or by locating the gas outlet centrally in the top of the generator chamber. It is obviously radically wrong to locate the fuel magazine in the center, since this procedure increases the resistance in the center of the fuel bed where it is already high, and makes hard driving and high temperature next to the producer lining inevitable. On account of the low operating temperatures permissible, if clinker troubles are to be avoided, it is necessary not only to adopt very moderate driving rates, but to allow the greatest possible amount of time of contact between blast and fuel by making the active part of the fire very deep. In this way the equilibrium con-

dition for the ratio of CO to CO_2 can be more nearly approached, and the disadvantages of low producer temperatures from a gas-making standpoint compensated for in no small degree. On anthracite the rate of driving should not ordinarily exceed 8 lb. per sq. ft. per hour. For bituminous coals the rate may be considerably raised, and on good fuel may even go to twice this figure. The depth of fuel bed in either case should preferably be not less than 5 ft.

A very deep fuel bed has other advantages than simply to contribute to producer efficiency. When the producer is operating under varying loads, and particularly when a suction producer is supplying a gas engine, it must be prepared to meet sudden demands for increase of gas without too much alteration in gas quality. When

Fig. 7. Engines supplied with soft coal suction producer gas and driving direct connected 60 cycle, three-phase alternators and air compressors with automatic unloaders, belted to engine shaft. Service continuous, from Monday morning to following Sunday morning.

the producer is operating at light load it is probable that not more than 16 in. or 18 in. of the fire is engaged in active combustion. However, the fuel lying immediately above this is heated red hot simply by contact with the hot gases passing from the fire below. This red hot fuel is capable of entering into immediate combustion as soon as any air is brought into contact with it. Accordingly, when a sudden load is thrown on the engine, and a correspondingly sudden demand for gas is made, the increased velocity of flow through the fuel bed immediately draws air into the upper layers which, al-

though red hot, have not been chemically active. These upper layers are capable of instantly supporting combustion, and they contribute in this way to maintaining uniform gas quality, and permit the producer to respond to variations in load that could not otherwise be met. The large mass of fuel within the producer has a correspondingly large store of thermal energy, and exerts by its mass a very desirable steadying effect on the whole gas-making process. The producer is accordingly able to carry over sudden demands simply by virtue of heat energy previously stored in the fuel bed, which may be gradually restored later, and thus performs, to some extent, the function of a thermal fly-wheel.

When we consider the gasification of coals containing volatile matter, another element is introduced which requires most careful attention. Not only does the presence of hydrocarbons affect the method of gasification in the producer by introducing a distillation process which must be carried on at the expense of heat generated in the gasification of the fixed carbon, but the problem of maintaining a uniform gas quality is complicated by the rich hydrocarbons from the destructive distillation of the fuel, and the cleaning of the gas must be carried out with much greater thoroughness. It is in connection with this class of fuels that the most interesting work is being done at the present time in the field of producer design. It is accordingly not inappropriate that the various plans that have been suggested and promoted for the gasification of bituminous fuels should be briefly discussed.

The remarks in this connection relate, of course, almost entirely to the production of gas for power purposes, although the importance of uniform gas quality for furnace work is coming daily into greater prominence. The ordinary type of up-draft producer for bituminous coal cannot possibly produce a uniform grade of gas. Not only are the methods employed for saturating the blast utterly inconsistent with close regulation of the blast quality, but the ordinary method of distilling the volatile matter from the coal is such as to make uniform gas production impossible. The distillation of volatile hydrocarbons from bituminous coal is a process that absorbs considerable heat. It can take place, therefore, only where this heat is being supplied either by combustion in the immediate neighborhood of the fuel being distilled, or by contact with hot gases proceeding from a portion of the fuel bed which is maintained at high temperature. In the ordinary type of fuel producer, the fresh fuel is simply dumped onto the top of the fuel bed and exposed to the hot gases issuing from the burning fuel immediately beneath. When a fresh charge of fuel is dropped, a rapid evolution of hydrocarbon gases results with a corresponding rapid increase in gas value. After the fuel has been exposed to this temperature for some time, the production of volatile gases diminishes, but the coking of the fuel is not complete until the coal has

descended into the very hottest region of the fire, since very high temperatures are necessary to drive off the last volatile matter from the coal. To overcome the difficulty from variation in gas quality resulting from sudden distillation of hydrocarbons from the coal, two general methods have been suggested; first, by regulating the rate of distillation of hydrocarbons, and second, by so altering the characteristics of the distilled gases by suitable chemical reactions that they will not differ materially in heating value from the gas resulting from the gasification of fixed carbon. Both of these processes are to some extent successful, and the degree to which each may be successfully applied is a matter of no little interest. The chief argument in favor of the first method, namely, regulating the rate of distillation without altering the characteristics of the dis-

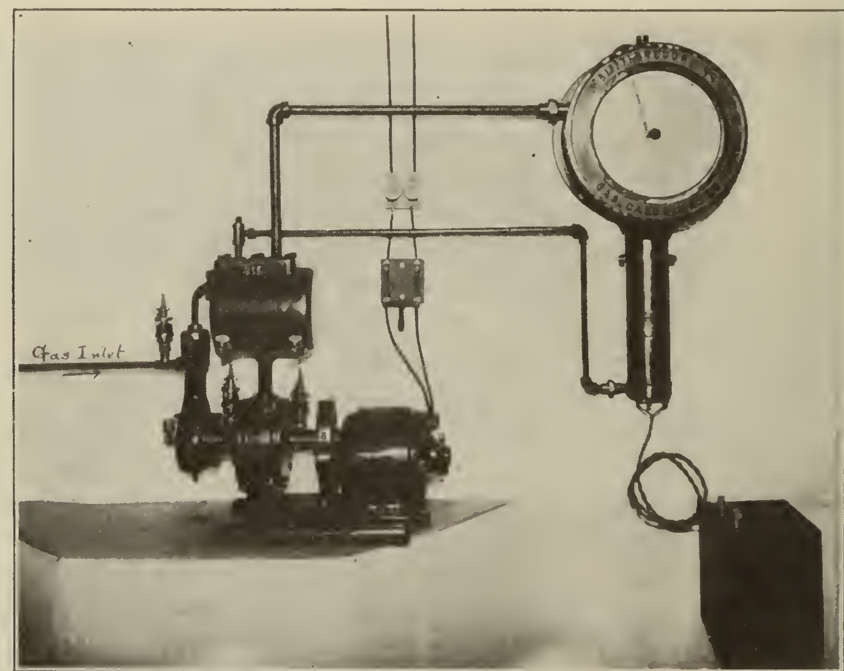

Fig. 8. Smith Recording Gas Calorimeter, with Sampling Pump and Pipe Connections.

tilled gases, lies in the fact that this process permits the use of a very simple type of up-draft producer, and results in the production of gas that is of materially higher heating value per cubic foot than can be produced from fixed carbon alone. These advantages are not to be considered lightly. Simplicity of apparatus is certainly much to be desired, and the production of gas high in heat value has an important bearing on the cost of gas power equipment, since the power that can be developed by an engine of given cylinder displacement depends, to a considerable degree, on the minimum heat value of gas supplied. The cost of equipment, therefore, to satisfactorily accomplish a given work will be materially

lower when a gas of high heat value is produced. It has been maintained that more satisfactory results can be secured from low heat value gas, since the engine efficiency can be raised, by increasing the compression, to a point where just as much power can be developed as with a richer gas. While this is undoubtedly true, this increase in power and efficiency is always accompanied by a necessary increase in the strains on the various working parts sufficient to demand heavier construction, or, lacking this, the operation of the plant on a lower factor of safety.

The chief interest that attaches to the various means that have been suggested for altering the chemical character of the distillation products from bituminous fuel, lies in the possibility of eliminating tar by this process, and thereby simplifying the cleaning plant required. Two methods have been most frequently employed for treating the hydrocarbon vapors to alter their chemical characteristics: First, decomposition by heat; second, combustion with oxygen.

If tar-free gas is to be produced by either of these processes, it is essential that the conditions for chemical alteration of the volatile hydrocarbons must be maintained until the final trace of volatile has been driven from the coal. In other words, the coking of the fuel must be absolutely complete before the coke can be considered as fixed carbon and treated differently than would be permissible for the bituminous fuel from which it is produced. This means that the distillation process whereby the volatile matter is separated from the fixed carbon in the fuel must be unusually thorough. It is interesting to note that ordinary gas-house coke is not by any means sufficiently carbonized to be considered fixed carbon for producer purposes. Likewise, charcoal contains too much bituminous matter to be used in an ordinary up-draft producer without special provision for removing tar from the gas before it is passed to the engine. The process of distillation whereby the volatile matter is driven from the coal must be materially more thorough than that employed in the ordinary bench gas process, or in the production of charcoal, if tar-free gas is to be generated from it. If we assume, however, that this distillation process has been satisfactorily carried out, and the volatile matter completely separated from the fixed carbon, its subsequent treatment demands further consideration. These hydrocarbons can be completely converted into fixed gas and carbon by exposure to a sufficiently high temperature for a sufficient length of time. It would seem, therefore, that all that would be required would be to pass the volatile hydrocarbons, as liberated, through a bed of incandescent fuel. thereby heating them to a high temperature, and bringing about their decomposition into carbon and fixed gas. Unfortunately, while it is relatively easy to bring about a partial decomposition in this way by the use of heat alone, it is not by any means so easy to

make the decomposition complete. The tendency of hydrocarbons treated in this manner is to split up into two portions, one of which is a fixed gas and the other a mixture of hydrocarbons more dense than the original body. This process may be continued to its finality, but as each step of the reaction takes place the next requires the use of higher temperatures and longer time of exposure for its completion. If a sufficiently high temperature could be maintained within the fuel bed, and the hydrocarbon gases brought to this high temperature and held there for a sufficient length of time, the pro-

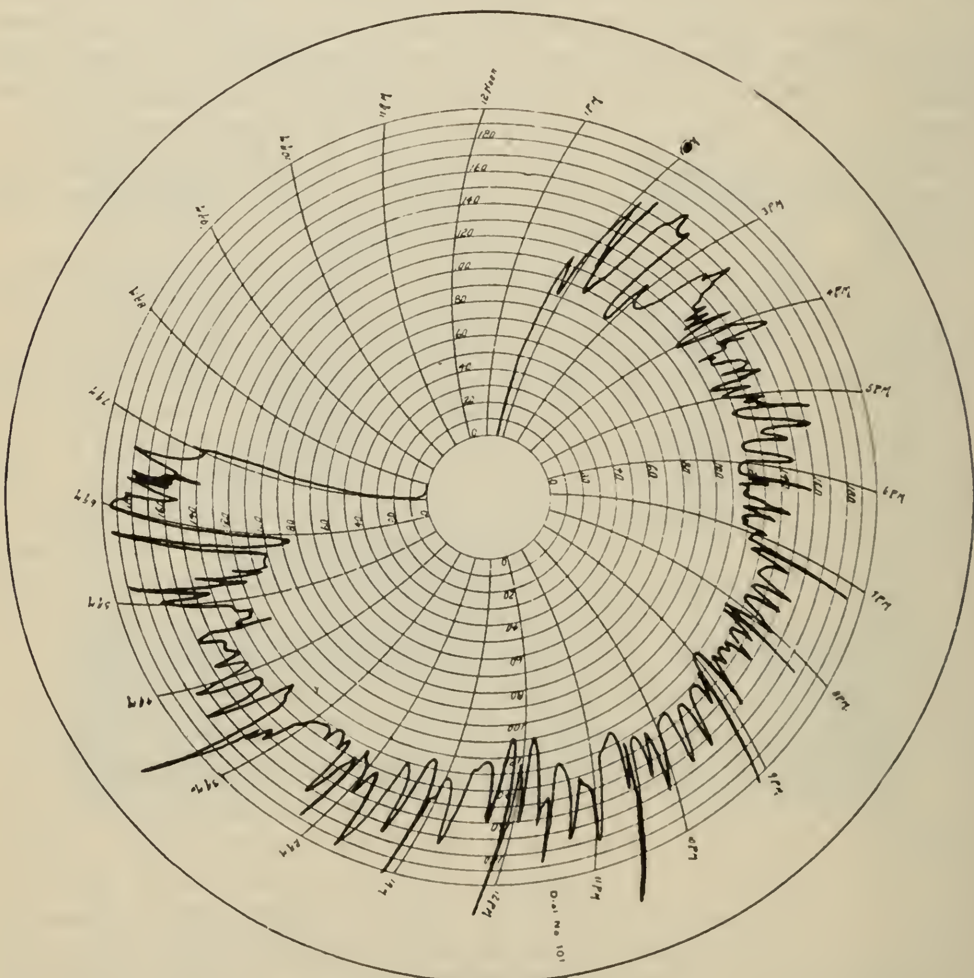

Fig. 9. Showing Rapid Variations in the Thermal Value of the Gas.

duction of perfectly tar-free gas from these hydrocarbons could be accomplished. Generally, however, it is found that the temperatures required and the time of contact necessary for such a complete reduction, are both beyond the range permissible in producer practice. We have already seen that we are strictly limited in our producer operations to a temperature that is below the fusing point of the ash contained in the fuel, and with most American fuels this tem-

perature is considerably too low to cause the complete dissociation of the hydrocarbons given off during distillation. Consequently, while a process of treatment of this kind will result in a considerable reduction in the amount of tar, the resultant gas will nevertheless be by no means tar free.

A more ideal method for handling these hydrocarbons would seem to be offered by the process of complete combustion. The hydrocarbon vapors given off by distillation are extremely inflammable. If they are completely burned with air to their elementary products of combustion, namely, CO_2 and water vapor, all elements that might possibly contribute to the production of tar or lamp-black would be removed. These products of combustion would be very highly heated by their combination with oxygen, and could easily be regenerated into combustible gas by being passed down through the fixed carbon remaining from the destructive distillation. In this way a perfectly clean gas, free from either tar or lamp-black and of uniform chemical composition, and consequently of uniform heat value, could be produced.

Many producers have been designed in an effort to incorporate this principle in a commercial machine. Two fundamental difficulties are encountered which are independent of any question of design, and which have a very material bearing on the success of this type of apparatus. The first of these is the difficulty of securing sufficient completeness in the coking or distillation process. The thorough coking of any fuel containing a considerable quantity of bituminous matter is a process that requires not only high temperature, but considerable time. The fuel is heated from without inward, and time is required for the heat to penetrate to the interior of the lump of coal. This penetration is continually hindered by the current of volatile matter that is passing out toward the surface of the fuel from within. Driving off the last traces of volatile matter requires a very high temperature, and the combined requirements of high temperature and long time of exposure make a difficult problem. Of course the complete distillation of hydrocarbons is absolutely essential in all double-draft machines; that is to say, in machines in which the fixed carbon is gasified up-draft after the manner of the ordinary up-draft producer. It must be assumed, in machines of this type, that nothing but fixed carbon is delivered in the up-draft zone, since any volatiles proceeding from this part of the producer would pass out of the gas outlet unfixed. This process of distillation can be materially hastened and made more complete if a portion of the fixed carbon is consumed during the process of distillation. This not only materially increases the available heat, but by reducing the size of the lumps of fuel by removing carbon from the surface it favors more rapid coking. However, any combustion of fixed carbon increases the second difficulty of which we will now make mention.

It is evident that if complete reduction of the hydrocarbon vapors without formation of either tar or lamp-black is to be attempted, these must be completely burned to their ultimate products of combustion—carbonic acid and water vapor. It is therefore pertinent to inquire whether or not there is sufficient fixed carbon in the fuel to reduce the products of combustion arising from the complete burning of the volatile hydrocarbons. In order to bring this matter clearly to mind, the writer has selected four more or less characteristic American coals. The chemical analysis of these fuels

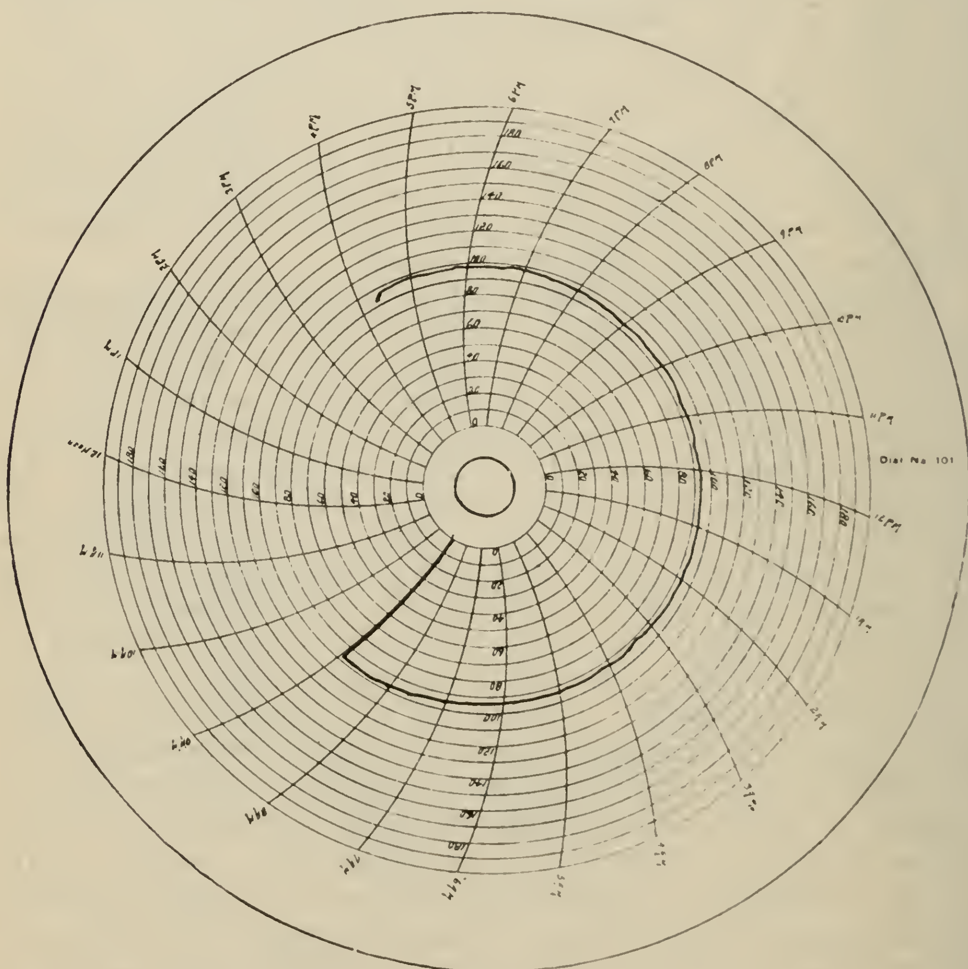

Fig. 10. Calorimeter Chart Showing Record on Blast Furnace Gas.

is taken from the U. S. Geological Survey report. The first of these is Pocahontas. Chemical analysis of this coal shows a total of 90% carbon, of which 80% is fixed carbon and 10% is combined with 4.6% hydrogen to make a total of 14.6% volatile matter. To completely burn this volatile matter would require for the carbon 27 parts by weight of oxygen to form CO_2 and for the hydrogen 37 parts by weight of oxygen to form H_2O. These products of

combustion to be completely reduced to CO and H would react with 50 parts by weight of fixed carbon. The Pocahontas coal, however, contains 80 parts by weight of fixed carbon so that there would be, with this fuel, an ample supply of fixed carbon to reduce completely the products of combustion of the volatile matter, and with a sufficient margin to cover contingencies and imperfections in the process. Considering, in the same way, a West Virginia coal from the Fairmont District, we have 63% fixed carbon and 28.6% volatile matter. If this volatile matter is completely burned 56 parts by weight of fixed carbon would be required to reduce the products of combustion. This coal contains 63% by weight of fixed carbon, so that we can reasonably expect this process to be practical with coal of this quality *if no fixed carbon is burned during the distillation process.* If we consider, in like manner, a characteristic Illinois coal, we find it to contain 50% fixed carbon and 27% volatile matter. To completely reduce the products of combustion of this volatile matter, 57% of fixed carbon would be required. With this grade of coal, therefore, it would seem to be

Coal	Fixed Carbon	Volatile		Oxygen to burn volatile to CO_2 and H_2O	Carbon necessary to reduce CO_2 and H_2O from combustion of volatile to CO and H.
	C	C	H		
Pocahontas	80	10	4.6	64	38
W. Virginia	63	23	5.6	106	56
Illinois	50	21	6.1	104	57
Indiana	49	25	6.2	116	61

impossible to carry out this sort of producer process efficiently, even if we assume that the volatile matter could be completely driven from the coal without loss of fixed carbon, and that these volatile products could be completely burned without excess of air. Since neither of these propositions is commercially practical, it is seen to be a physical impossibility to operate a producer on Illinois bituminous coal on this principle. Considering, in the same way, a characteristic Indiana coal, we find the fixed carbon to be 49%, the volatile combustible 31%, and the fixed carbon required to reduce completely the products of combustion resulting from the volatile combustible material to be 61%. There is available in this coal, however, only 49% fixed carbon. It is therefore seen that this coal is also impractical for this method of operation. Of the four coals considered, it is plain, if any reasonable allowance is made for the unavoidable imperfections of the process, that only one, namely, the Pocahontas coal, possesses the necessary characteristics to permit this process to be successfully carried out. The great majority of bituminous fuels, available in this country at least, are not amenable to this process of treatment owing to inherent defects in their composition. This process cannot be applied with

any prospect of commercial success on fuels containing less than about 75% fixed carbon. When fuels containing less fixed carbon than this are used, the process must be more or less incomplete at one point or another. If the volatiles are completely reduced so that neither tar nor lamp-black are formed, then the producer operation must necessarily be inefficient, since a portion of the products of combustion must pass forward unreduced, and stand as an unavoidable loss in the gasification process. If, however, the combustion of the volatile matter is not complete, that is to say, if insufficient air is supplied to completely burn them, then the production of tar or lamp-black is unavoidable. Neither of these processes is carried out completely in any form of commercial apparatus. The ordinary down-draft producer may be taken as representative of most of the attempts that have been made in this direction. In this the distillation process is materially aided by the combustion of a part of the fixed carbon. The volatile matter is partially burned in contact with an insufficient supply of air, this process resulting in the liberation of lamp-black from the hydrocarbons. Those hydrocarbons that escape combustion, either complete or partial, are to some extent broken up in passing through the incandescent carbon in the lower levels of the producer and converted by heat into fixed gas and tar, or, if the fuel bed temperature be sufficiently high, into fixed gas and coke. No producer yet designed for bituminous fuel has succeeded in producing a gas that is at all times sufficiently clean to make the use of efficient cleaning unnecessary.

The materials to be removed from gas in the cleaning process vary with the fuel from which the gas is derived. With blast-furnace gas the impurities to be removed consist almost entirely of inorganic dust arising from the iron ore and limestone fired to the furnace. In gas from anthracite, the principal impurities to be removed, aside from the relatively small amount of fine ash which is carried over, consist almost entirely of sulphur or some compound of sulphur in a finely divided state. The deposit occurring in piping and valves from anthracite producers always contains a large percentage of sulphur, if this substance is found in any considerable quantity in the coal. It is probable that this sulphur dust originates from the spontaneous decomposition of various sulphur compounds in the gas, many of which can undergo chemical changes at ordinary temperatures with the liberation of sulphur dust. Gas from bituminous coal will require purification from tar or lamp-black or both, depending on the processes used in treating the hydrocarbons in the coal. In connection with the utilization of gas from bituminous coal, the point on which the most serious question is usually raised is on this matter of gas cleanness, and particularly on freedom from tar.

In order that some idea may be gotten of the problem involved in purifying gas from bituminous coal, the writer has recently con-

ducted some investigations that will enable him to present to you a few figures representing, approximately at least, the characteristics of tar in producer gas. In raw bituminous producer gas, the tar is carried in the form of minute particles, or, as it is commonly designated, as tar fog. In the particular case investigated by the writer, the gas carried a total of approximately 4 grains of tar per cu. ft. The tar particles were found to vary in size from about 0.00008 to 0.00015 in. in diam., the average size being in the neighborhood of 0.00010 in. The number of tar particles was found to be somewhere in the neighborhood of 20,000,000 per cu. in. These particles are so small and their ratio of surface to mass so great that they are influenced almost entirely by their surface relations with other bodies and very slightly by their mass. The viscosity of

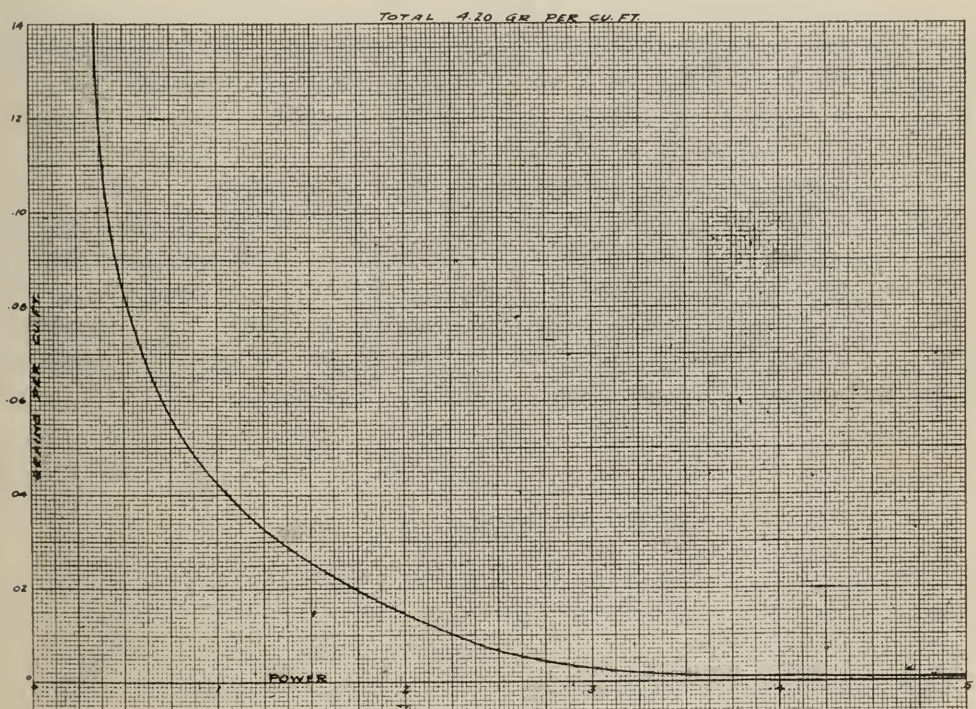

Fig. 11. Curve Showing Reduction of Tar in Gas.

the gas is so great that the tar particles move through it very slowly. The surface action predominates to such an extent that it is impossible to separate the tar particles from the gas by centrifugal force alone, even though the difference in density between the gas and tar fog is very great. It might be remarked here that the so-called centrifugal tar extractors do not operate by the action of centrifugal force on the tar particles but in an entirely different manner. These particles are so minute that any ordinary filtering medium will not trap them. The particles will pass freely through the meshes of almost any woven fabric. When passed slowly through as much as ¼ in. of wool felt, the issuing gas still contains a con-

siderable quantity of the tar fog. In view of the smallness, the elusive property and enormous number of these particles, the results that can be attained in cleaning producer gas with suitable appliances are certainly remarkable. There are a number of systems of cleaning producer gas that are more than 99% efficient; that is to say, of the 20,000,000 tar particles contained in a cubic inch of raw gas it is comparatively easy to remove 19,800,000 by suitable processes. When the quantity of gas required in a power plant of very moderate dimensions is taken into consideration, the work to be done by a scrubbing plant assumes enormous proportions. A 200 h. p. plant, for example, will use approximately 16,000 cu. ft. of gas per hour. In a plant of this size the cleaning apparatus is under the necessity of removing from the gas 140,000,000,000 tar particles per sec. No practical method has yet been devised for removing absolutely all of the tar from the gas, but by the use of appliances that need not be at all complicated, it is possible to bring the cleaning plant to a very high degree of effectiveness. It is at present not beyond the range of possibility to produce, in a commercial way, gas containing not more than 0.001 of a grain per cu. ft. This implies a scrubbing efficiency of 99.99%. Gas may be considered sufficiently clean for gas engine use under any ordinary conditions if the impurities are reduced to less than 0.03 of a grain per cu. ft. From this it would seem that the margin between the necessary degree of gas cleanness, and the possible degree of gas cleanness, is sufficient to constitute an ample factor of safety.

CHEMISTRY OF SEWAGE PURIFICATION

Methods Employed at the Chemical Laboratory of the Sanitary District of Chicago.

DR. ARTHUR LEDERER.*

GENERAL.

Sewage may be purified in part either by mechanical, chemical, or biological means, in combination or separately. Thorough knowledge of all the agencies at work in the biological purification of sewage has not been attained. The clarification of sewage by chemicals is easily explained by the reaction taking place, and the mechanical action of the floc formed. Since biological treatment is very largely used, more time will be devoted to that general process.

Unless specifically stated to the contrary, the remarks in this paper refer to dilute domestic sewage, and not to trade wastes. The treatment of sewages containing trade wastes, or of trade wastes themselves, is a problem in itself, requiring many different processes. The chemistry of the purification of trade wastes depends largely on the character of the wastes. As a rule, such wastes do not interfere with the common methods of disposal, unless they are present in excessive quantities, or are poisonous, either to men, animals, or fish.

PHYSICAL CHARACTERISTICS.

The physical characteristics of a weak domestic sewage, from a large sewerage area as represented by the area draining to the 39th Street testing station, in Chicago, are subject to variations, depending, in part, on the rain-fall or snow-fall. In dry weather the sewage appears turbid, with a yellowish cast from the urine and feces; a perceptible quantity of settling suspended matter is present, in color ordinarily light gray, changing to dark gray, or even black in the storm-water sewage. The odor of the fresh sewage is slightly gaseous, but not at all repugnant as might be supposed. Other sewages might show different physical characteristics, depending upon the water consumption and other factors. As a rule, American sewages are far more dilute than foreign sewage, because of the great waste of water in the United States. A European sewage may, therefore, have not only a more repugnant appearance, but will often possess a

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strong putrid odor. The development of such an odor depends upon the amount of oxygen in solution.

CHANGES IN SEWAGE ON DECOMPOSITION.

The sewage handled at the 39th Street testing station contains some oxygen in solution, as well as nitrites and nitrates, during the greater part of the year, in particular during the winter. Such a sewage is called a fresh sewage. When the oxygen content—the dissolved oxygen as well as the oxygen in the nitrites and nitrates—becomes exhausted, the sewage turns stale, and the organic matter begins to break down, marking the first step toward the ultimate mineralization of the organic putrescible matter,—a change due mainly to the powerful activity of bacteria and enzymes. At this stage the free ammonia gradually increases, combining with the carbon dioxide to form ammonium carbonate. The organic carbon is oxidized as long as free oxygen persists in the sewage. Eventually anaerobic decomposition follows, resulting in the formation of gaseous decomposition products, of which hydrogen sulphide is very prominent. Free nitrogen is likewise released. The sewage becomes *septic*. The larger the proportion of putrescible matter present, and the smaller the amount of oxygen in solution, the quicker does a sewage become septic. The carbonaceous and nitrogeneous compounds present in the sewage are further attacked by anaerobic micro-organisms,—an action which frequently produces a nuisance.

The term *septic* has never been strictly defined, but may cover the lack of oxygen in the fluid, and the toxic or septic effect of anaerobic decomposition products upon aerobic organisms. Sometimes reference is made to an *over-septic* condition, which, to the writer's understanding, is one based upon the inhibition of the growth of anaerobic organisms by their own decomposition products. The term today is used vaguely, and requires standardization.

PHYSICAL RECORD.

In our laboratory we record the physical properties, as well as the quantities of settling suspended matter in the sewage, and any peculiarity in color. Sometimes the color becomes distinctly yellowish, a reddish precipitate gradually settling out. In such a sample the alkalinity is found to be low, and the sulphates high. We have traced this to the discharge of pickling liquor wastes from a wire works.

PRESERVATION OF SAMPLES.

The odor of samples of sewage, or purified effluents, is not recorded as a routine procedure. The reason is that the samples are collected over 24 hours for crude sewage, and over 48 hours

for other effluents. To avoid change in the chemical constituents, a preservative is added,—in our case chloroform to the amount of 10 c.c. to one gallon of sewage. The chloroform effectually hides any odor present, unless hydrogen sulphide occurs in large quantities. As an additional precaution, the samples are kept in cold storage up to the time of analysis.

Exhaustive study into the question of the preservation of sewage samples has shown us that, even in a storage period as short as 6 hours, perceptible changes will occur in the nitrogeneous constituents of a fresh unpreserved sewage. At room temperature, the addition of 10 c.c. of chloroform to one gallon of sewage checks the decomposition to some extent, but even in such cases, immediate analysis is often desirable to obtain accurate results. Cold storage alone is a fair preservative. The combination of chloroform and cold storage is the best obtainable method at present. An ideal preservative is lacking for liquids, like sewage, of changing character. It should be odorless and colorless, and should not affect any of the constituents present or interfere with the analytical determinations.

SUSPENDED MATTER.

During the various stages of sewage purification, it is important to observe the physical and quantitative changes in the suspended matter, since the aim today is to remove as much as possible at the outset, in order to obtain a fresh effluent. In studying the efficiency of a device, frequent determinations are necessary both for the influent and effluent, extending over a considerable period, before an opinion can justly be formed of the percentage removal of suspended matter.

The settling suspended matter should be clearly distinguished from the non-settling suspended matter, in studying the efficiency of a settling device. Much of the suspended matter in sewage, particularly on large areas, occurs in a finely divided, or colloidal state, not capable of sedimentation even on prolonged storage; hence, when a settling tank is removing perhaps 35% of the total suspended matter, it may actually be taking out 100% of the suspended matter capable of settling. On prolonged storage, however, some of the colloidal matter may coagulate, and material previously in solution will also change to apparent settling matter. This is particularly true for strong sewages. From our analysis of the composition of the settling and non-settling suspended matter, it is evident that the percentage of volatile matter is greater in the non-settling portion. This may have a very important bearing upon the true character of a settled sewage from the standpoint of a prospective nuisance in a stream.

The settled suspended matter is termed *sludge*. The percentage of volatile and fixed matter depends upon the character

of the sludge, a fresh sludge containing more volatile matter than fixed matter, a septic sludge being higher in mineral constituents. The content of moisture may run from 85% to 95%, depending upon the device.

Since the determination of the settling suspended matter is of importance in the control of a sedimentation plant, the daily variations may be advantageously followed by determining the loss of suspended matter on settling gravimetrically, or else by measuring the number of c.c. of settled matter in a conical-shaped glass holding one liter. Such glasses are used in Germany, and may be of value in dealing with strong sewages containing considerable amounts of settling suspended matter, but in our weak American sewages the control is not as satisfactory, since the 39th Street sewage, for instance, contains, on an average, only 140 p.p.m. of total suspended matter, of which from 40% to 50% is capable of settling. In our case, actual gravimetrical determinations are made of the total volatile and fixed suspended matters by the Gooch crucible method.

Sprinkling filter effluents contain, as a rule, some suspended matter, but of a different character from the original floating or colloidal matter. A sprinkling filter is not built primarily as a means of removing suspended matter, but as a machine to oxidize and mineralize the organic material delivered to it. In the long run, a sprinkling filter should deliver, in its effluent, nearly as much solid as received. At times the effluent may be very clear. Some observers claim that more is delivered. The effluent, however, is greatly improved from the chemical standpoint, and also from the standpoint of putrescibility. The suspended matter, when unloaded, may give rise to putrefaction if stored in considerable quantities, and may become septic, so that shallow secondary settling basins may change a non-putrescible filter effluent into a putrescible final effluent.

OXYGEN CONSUMED.

The time-honored *oxygen-consumed* test indicates the amount of oxygen absorbed by the oxidizable matter during titration in acid solution with permanganate, and in particular the amount of organic carbonaceous matter present. At present there are so many modifications of the test, that the results from various laboratories cannot be directly compared, without knowledge of the method employed. In our laboratory the 30-minute water bath boiling method is used. For comparative purposes this is a valuable test, although the figures obtained do not represent anything absolute. The result covers only a small percentage of the total carbon. The organic carbonaceous compounds vary in their resistance toward acid permanganate solution. The average of the oxygen consumed in our sewage is about 50 p.p.m.; the

average of the effluent of a sedimentation tank is about 40 p.p.m.; and the average in our sprinkling filter effluent is about 25 p.p.m.

It is important to remember that the oxygen-consumed test does not represent the oxygen which the liquid would absorb under natural conditions in a water course. From the practical standpoint, a far superior test is one which indicates quantitatively the rate at which oxygen is absorbed in fresh water. I would style this the *biologic oxygen-consumed test* in contradistinction to the *permanganate oxygen-consumed test.* I shall refer to this later.

NITROGEN.

Nitrogen in its various forms represents the never ending cycle in the conversion of animal into mineral matter, and vice versa. The organic nitrogen, in decaying, splits off ammonia which, in turn, becomes oxidized to nitrites and then to nitrates, not by simple chemical oxidation, but through the activity of various micro-organisms, of which very little is understood. Extensive bacterial research on the problem of nitrification has been made by Winogradsky, Frankland, and others. That the process of nitrification is a bacterial one is not in doubt, since Schlösing and Muntz demonstrated that when solutions containing ammonia were allowed to percolate through the soil, the ammonia was converted mainly into nitrate, but if the living organisms in the soil were paralyzed by chloroform vapor, or other antiseptics, nitrification did not take place. For the activity of these organisms the presence of oxygen is essential, as well as of a base to neutralize the nitrous and nitric acid which is formed. Moderate temperatures are most favorable, but the action may take place even at temperatures as low as 3° or 4° Cent. Species have been isolated which require very little or no organic matter for their subsistence. Such bacteria seed themselves in biological filters, and nitrify or mineralize the material coming to them. In general, the larger the bacterial surface the greater the nitrification will be for a given application of liquid. The size of the material and rates of application have to be varied for the process attained. In an intermittent sand filter, only 100,000 gallons can be applied to an acre in a day, whereas in a coarse grain sprinkling filter from 2,500,000 to 3,000,000 gallons can be applied to an acre in a day. A sand bed 3 ft. deep would give a much higher nitrification than a sprinkling filter bed 5 ft. deep of stone from 1½ to 2 in. in size, at the rates mentioned. Overloading a filter will interfere with nitrification. It is interesting to note how short a period is required to establish nitrification on a large scale. The nitrates represent the last step in the oxidation of the nitrogenous matter, and serve as food for the higher developed living organisms. These

organisms, in dying, form the starting point of another nitrogen cycle.

As yet our understanding of the nitrifying organisms, and the processes involved, is very meager, so that in the future, research will be desirable to learn the exact action taking place. Possibly the nitrification process can be intensified by artificial means.

DE-NITRIFICATION.

It is interesting to note that certain species of bacteria have the power of reducing nitrates to nitrites, free ammonia, and free nitrogen, in contradistinction to the nitrifying group. Grayson and Dupetit made the first observations in 1882, and concluded that denitrification was essentially the result of combustion of organic matter by the oxygen of the nitrates. Frankland and Beyerinck have added to our knowledge. Many organisms have been found which do bring about denitrification.

Because of the research into the protein molecule, I wish to speak of the nitrogenous intermediate products, which in sewage disposal are frequently productive of disagreeable odors, as for instance indol, with its putrid odor, or ammonia, with its characteristic odor. Free nitrogen, as mentioned, is produced by the denitrifying action.

SIGNIFICANCE OF NITROGEN CYCLE.

The nitrogen cycle offers a good index to the efficiency of a modern sewage filter of any kind. In a settling tank we do not expect much change in the nitrogen, except the elimination of some of the organic nitrogen in the settling suspended matter. In a more extended storage period the free ammonia may increase, and the nitrates and nitrites decrease, provided the sewage originally applied was not *septic*. In a septic tank the free ammonia ordinarily increases, and the nitrates and nitrites decrease, or become entirely eliminated. The increase in the free ammonia in a septic tank results from the reduction of nitrates and the breaking down of the organic nitrogen. The biologic treatment on sprinkling filters and sand filters is an oxidizing process, and should result in an increase of the nitrates and nitrites. The organic nitrogen is decreased in a filter, on account of the bacterial decomposition and the escape of the volatile nitrogenous products and free nitrogen proper.

DETERMINATION OF NITROGEN.

The organic nitrogen, as well as the free ammonia, the nitrates and nitrites, are determined as a routine procedure on all our samples from the sewage testing station. The method for the determination of the organic nitrogen is that introduced at the Columbus testing station, and consists in the digestion of the sample by concentrated sulphuric acid, subsequent neutral-

ization and direct nesslerization. The free ammonia is distilled previous to nesslerization. Very often the sample is nesslerized directly after adding a few drops of potassium hydrate and copper sulphate, the resulting precipitate being allowed to settle. The nitrates are determined by the napthylamine-sulphanilic acid method, and the nitrates by aluminum reduction in alkaline solution.

FORMATION OF HYDROGEN SULPHIDE.

Another interesting topic in the chemistry of sewage is the formation of hydrogen sulphide, the history of the sulphur cycle resembling that of the nitrogen cycle. Its presence in sewage indicates putrefactive changes as a rule, since sulphur is an element of the protein molecule, and as such is always present in small quantities in sewage. Plants absorbing mineral sulphates convert them into organic sulphur. On breaking down, organic sulphur yields hydrogen sulphide which becomes oxidized again to sulphates, either by chemical or biological means. Just as nitrates can be reduced to free ammonia, so are sulphates capable of reduction to hydrogen sulphide. Apparently the sulphur cycle is influenced more by purely chemical reactions than is the nitrogen cycle, but in both cases the changes are largely the result of bacterial activities.

The principal question for further study is the generation of hydrogen sulphide from inorganic sulphates, since hydrogen sulphide is one of the constituents most intimately connected with the development of a nuisance, and may also be responsible for damage to concrete work. Practically all sewage bacteria will form the gas in artificial media containing sufficient organic sulphur. Any sewage containing hydrogen sulphide may form a black sediment typical of septic conditions, the sediment consisting mainly of ferrous sulphide, since iron is almost always present in sewage in varying amounts. Other gases, however, may originate from the destruction of organic sulphur, as for instance, mercaptan. The formation of hydrogen sulphide, however, from sulphates is of more importance perhaps than its formation from organic sulphur, since sulphates are often present in large quantities. The reaction is undoubtedly due to specific types of bacteria, rather than to a wide group. Beyerinck first noted the phenomenon, and stated that the best conditions for the reduction of sulphates were the absence of oxygen, the absence of sugar in the culture media, and the presence of phosphates and other suitable solids. Only small quantities of nitrogen compounds are necessary. The optimum temperature is around 25° Cent. Beyerinck isolated an organism, the spirillum desulphuricans, a strictly anaerobic organism reducing sulphates. Other important work has been carried on by Van Delden, Letts, and recently by Dr. Buchanan.

September, 1912

SIGNIFICANCE OF HYDROGEN SULPHIDE.

Hydrogen sulphide in sewage may not only be responsible for a local nuisance, since amounts as small as 3 p.p.m. can be noted under outside conditions, but on discharge into a stream it will draw upon the dissolved oxygen present, and often to such an extent that fish life will be seriously interfered with. In addition, hydrogen sulphide by itself is a poison to fish. The reduction of sulphates has been observed in many sewages in the United States and abroad, particularly when the sulphates are high from the introduction of trade wastes. In some cases the disintegration of concrete has been a serious matter, due to the oxidation of hydrogen sulphide to sulphuric acid by the atmospheric oxygen.

One of our settling tanks, a modified Dortmund tank, or, as Professor Phelps calls it, a biolytic tank, affords a typical case of active sulphate reduction. At times as much as 40 p.p.m. of hydrogen sulphide have been observed in the effluent. This can be traced directly to bacterial activity.

Before dismissing this topic, I will mention the classic work of Winogradsky, who made an exhaustive study of the oxidation of free sulphur by higher bacteria, such as beggiatoa. The beggiatoa utilize the sulphur as a source of energy, taking up from two to four times their weight without increasing in growth. Requiring but small quantities of organic matter they flourish in sulphur springs, the decomposing hydrogen sulphide liberating amorphous sulphur. The sulphur in turn is oxidized to sulphates. The effluent of our biolytic tank is quickly oxidized in a sprinkling filter. The effluent of the filter, however, contains abnormally large amounts of sulphate, and the top of the filter is covered by a silk-like growth of sulphur bacteria.

In a sewage-disposal plant there is, as a rule, no occasion to test for hydrogen sulphide as a routine procedure. The sense of smell or a simple lead acetate paper test should suffice, unless some peculiar case requires special investigation.

CHLORINE.

The chlorine in a domestic sewage originates largely from the urinary chlorine, and indicates approximately the strength of a sewage. It can be easily determined by direct titration with silver nitrate solution, using potassium chromate as an indicator. Except as an index to the strength of the sewage, the chlorine determination has no further significance. The presence of industrial wastes containing chlorine, or of ground waters or sea water, may prevent us from drawing conclusions. On an average, the sewage of 39th Street contains about 40 p.p.m. of chlorine, indicating a dilute sewage.

ALKALINITY.

The alkalinity has little significance in the interpretation of results, since industrial wastes may cause abnormal figures. Sewage ordinarily is slightly alkaline, considerable quantities of acid waste being required in order to turn it acid in the sewer. The average alkalinity of our sewage is 220 p.p.m., calculated as calcium carbonate. We titrate our sample with a 1/50 normal sulphuric acid. Methyl orange is used as an indicator.

FATS.

In domestic sewage the fats and fatty bodies result largely from the use of soap in laundries and from household wastes containing grease. On Mondays there is a slight increase in the fatty content of our sewage, but the addition is not great, since on our watershed there is a large proportion of apartment houses where washing is spread over several days of the week. No attempt is made to separate the fat from the soaps. On the addition of sulphuric acid, a certain quantity of sewage is evaporated to dryness, and the total fat extracted with ether. The average amount present in our sewage is approximately 25 p.p.m.

TOTAL SOLIDS.

The total solids in sewage are not now determined as a routine procedure, being largely of scientific interest. In our case the amount is about 600 p.p.m., or 0.6 of a gm. per liter. This indicates the extreme dilute character of our sewage.

DISSOLVED OXYGEN AND STABILITY.

Dissolved oxygen and putrescibility will be discussed together, since while both are determined separately, neither is by itself as instructive as when studied in connection with the other. The two determinations not only furnish a key to certain phenomena in biologic sewage disposal, but when their relation is better understood the solution of many problems will be attained. In a popular sense, putrescible matter is material which draws upon the oxygen in solution for its oxidation. However, inorganic compounds sometimes utilize oxygen in solution for their oxidation as well. From the standpoint of sewage disposal by dilution, or in studying the effect upon fish life, it is immaterial how the oxygen is used up. During the colder season, fresh dilute domestic sewages contain, as a rule, some oxygen which in a short time becomes exhausted, and anaerobic conditions set in. The liquid then enters a stage where oxygen is quickly absorbed when supplied in any form.

In the control of a sewage-disposal plant, the determination of the putrescibility is more important than the determination of the oxygen, and in comparison with the other constituents, the knowledge of the putrescibility or stability is of the greatest

importance. With this test a plant can be controlled to better advantage than by any elaborate chemical analysis. The reason for this is simple. The ultimate aim of any disposal plant is to make the putrescible matter more or less stable. The putrescibility test indicates the degree of oxidation obtained, and the determination of the dissolved oxygen gives a fixed figure of the absolute amount available for further oxidation. Both factors are important in studying a nuisance or fish life. A high oxygen content, in itself, does not indicate stability.

DETERMINATION OF DISSOLVED OXYGEN.

In our laboratory, the Winkler method has been used to determine the dissolved oxygen in the manner described in the "Standard Methods of Water Analysis" adopted by the American Public Health Association. The sample is collected carefully in order to avoid aeration. Manganous sulphate and an alkaline solution of potassium iodide are then added. The precipitate of manganous hydrate is allowed to settle; sulphuric acid is then added, and the free iodine in the solution titrated with standardized sodium thiosulphate. The equivalent of free iodine is calculated to oxygen. The results are expressed either in p.p.m., or in percentage saturation. In the latter case the temperature must be considered. Normal fresh water which has not undergone temperature changes ought to be 100% saturated, but may be sub-saturated or super-saturated, depending upon conditions, such as the season of the year, the sunlight, the presence of algae, or sudden changes of temperature.

As an alternative method, the American Public Health Association has recently recommended the Levy method for the determination of dissolved oxygen. This consists, briefly, in the conversion of a ferrous salt into a ferric salt by the oxygen in the water. The residual ferrous salt is titrated with the permanganate solution. At present the use of either method is a matter of choice.

Determinations for dissolved oxygen should be made on the spot to avoid a loss of oxygen, particularly in putrescible samples. From a study of this question in our laboratory, we have concluded that only fresh saturated and uncontaminated water like that from Lake Michigan can be kept for a number of hours without showing a reduction in oxygen. Even then the sample should be kept in a cool, dark place. The addition of a small quantity of formaldehyde allows an extension of the storage period, but it is preferable to add the first two reagents in the Winkler method in order to form the precipitate, where the determination cannot be made on the spot.

DETERMINATION OF PUTRESCIBILITY.

The putrescibility test has been almost universally adopted

by various sewage-purification plants. The one most in favor is the so-called methylene blue test devised by Spitta and Weldert in Germany. A dilute solution of methylene blue is added to a definite quantity of the effluent in a sterile bottle; the mixture is then incubated at 20° Cent. and the number of hours or days noted in which the blue color is discharged. This decolorization takes place only in putrescible samples and depends upon the formation of a leucobase when the oxygen in the sample has been exhausted. Some prefer an incubation temperature of 37° Cent. to obtain quicker results, but this temperature is not desirable because it does not conform to actual conditions as does the temperature of 20°. Furthermore a bacterial flora will flourish at 37°, which would not be favored at the lower temperature. Phelps has put the test on a quantitative working basis by which the putrescibility of a sample can be expressed in terms of relative stability. Such figures indicate the proportion of oxygen present as compared with the total amount required to effect the complete oxidation of a sample in question. The sample should be kept in the incubator for twenty days before being discarded, but from a practical working standpoint this is neither necessary nor desirable. Ten days storage as a maximum is sufficient, and often four days will give results sufficiently accurate for practical purposes. Samples which show signs of decolorization after four days may be held for further observation. The exact hour of decolorization is difficult to fix, but an experienced observer can avoid material mistakes in estimating the end point.

INDEX OF PERMISSIBLE DILUTION.

The putrescibility test outlined is eminently practical and valuable, but is not a quick method. Recently Phelps devised another method to give the desired information in a shorter time. The test in principle is not new, for it has long been known that organic putrescible material will absorb oxygen in solution, and the rate of absorption under certain conditions has rightly been looked upon as a good index to the putrescibility of the sample. Only recently, however, could the permissible dilution be calculated for a sewage effluent under certain assumed conditions. The procedure is to mix a small quantity of sewage carefully with fresh aerated water in definite proportions, and to incubate the mixture at 20° Cent. for a number of hours. To hasten the result, the dilution may be lowered. The dissolved oxygen is determined in the mixture at the start and again after the lapse of several hours. With these two figures in hand, the percentage of sewage permissible in a stream under assumed conditions can be calculated. In the formula are terms for the period of contact and the percentage of dissolved oxygen to be available at the desired point in the flow. With our present knowledge of

this test, the same assumptions must be followed from time to time in order to get comparable results, since the formula in its present state is not as perfect as may be, owing to the lack of knowledge of the shape of the curve for this bacterial reaction. The results obtained, however, are very practical and of great value. The method requires more accurate and careful work than the methylene blue test, and at present is open only to a skilled chemist.

BACTERIA.

Most of the chemical changes in biologic sewage purification are in reality the result of bacterial activity. The significance of these bacteria in general is of interest largely from the scientific standpoint. The removal of disease-producing bacteria, however, is a question of practical interest. Sewage disposal devices, in themselves, are not built, primarily, as bacterial removers, and cannot be relied upon unless sterilization of the effluent with chloride of lime be added as a sure means for removing bacteria. In a chemical precipitation process, the bacteria may be reduced partly by sedimentation and partly by the germicidal properties of the chemicals employed. In a plain settling tank the reduction of bacteria is due to sedimentation. In a sprinkling filter or in a contact bed the reduction is undoubtedly the result of mechanical detention as well as the action of higher developed organisms. The unfavorable environment may also be an influence. Secondary settling basins will reduce the number of bacteria again by simple sedimentation. The effluent of a filter may contain as low as 5% of the initial number of bacteria present originally. Biologic sewage purification may eliminate the putrescible matter, but if bacterial purification be desired, disinfection only will secure the result.

In our laboratory the method employed to determine the number of bacteria is to place 1 c.c. of the sample, properly diluted, in a litmus lactose agar medium. The temperature of incubation is 37°, and the time of incubation two days for the routine samples. It is well known, however, that no artificial medium—be it an agar or a gelatine medium—will permit the growth of all bacteria originally present. Therefore, the count per 1 c.c. indicates but a portion of the true number. More colonies will develop on gelatine than on agar.

METHODS OF SEWAGE DISPOSAL; DILUTION, AND SEDIMENTATION.

I shall not attempt to discuss here the question of sewage disposal by dilution, other than to point out that such a method is entirely legitimate within the oxidation capacity of the body of water into which the sewage is discharged. I will, therefore, turn to a consideration of the methods of preliminary treatment which may be covered by simple sedimentation, decomposition,

either aerobic or anaerobic, and chemical precipitation. In the operation of a sedimentation tank, sludge is removed frequently in the early stages of decomposition. The resultant improvement of the sewage from the standpoint of dilution will, of course, vary with the composition of the sewage and the amount of suspended matter present. We have recently demonstrated the fact that the simple removal of settling suspended matter improves the physical character of the sewage and its relative stability to some extent, but not to as great an extent as might be assumed from the actual physical improvement. In other words, the removal of 50 to 60% of the suspended matter will improve the character of the sewage from the standpoint of dilution from 25 to 30%. This means that the additional removal of the pseudo-colloidal matter will improve the liquid far out of proportion to the quantity of suspended matter thus removed. A device which would remove this fine suspended matter, without resorting to biologic treatment, would undoubtedly furnish an effluent which on a large scale would be intermediate between the preliminary or partial purification effected by settlement, and the more complete purification made by a sprinkling filter. In some cases it might suffice where preliminary purification alone would not.

SEPTIC TANK.

The anaerobic decomposition of sewage finds its widest application at present in the septic tank. This process may also be called a hydrolytic or liquefying process, and is substantially the same as that in the ordinary cesspool. The cellulose decomposes, forming hydrogen and marsh gas. Carbon dioxide and fatty acids are produced as by-products. Nitrogen is formed, probably due to nitrate reduction. Thirty-two degrees Cent. is the optimum temperature for the decomposition of cellulose; therefore a septic tank shows more violent ebullition of gas during the hot season, and frequently unloads large amounts of suspended matter. In our climate not enough gas is produced for any practical purpose, but at Matunga, in India, the gas from a septic tank has been utilized for driving an engine to pump sewage and for lighting and cooking purposes.

The ammoniacal fermentation taking place in sewage is due to the presence of urea. It starts readily and is frequently completed in the sewer itself. In septic-tank treatment the protein substances are the ones responsible for the foul odors, since hydrogen sulphide, mercaptan, indol, skatol, and various amines result from their decomposition. Fats when present in appreciable quantities may give rise to an objectionable rancid odor.

It is still a question whether the decomposition taking place in sewage under anaerobic conditions, as in a septic tank, is an advantage in the further purification. Current practice favors

the treatment of a freshly settled sewage. However, treatment of what may be called a "semi-digested" liquid has, apparently, some points in its favor, since compounds which are ultimately formed by these putrefactive processes yield more readily to oxidation than do the higher complex bodies originally present. On the other hand, the anaerobic decomposition products are probably inimical to the aerobic organisms present in the body of the filter.

BIOLYTIC TANK.

In our biolytic tank, a remarkable reduction of the organic nitrogen has taken place, accompanied by the excessive formation of hydrogen sulphide. The pseudo colloidal matter has been completely eliminated, leaving nothing save a slight amount of black sediment and the hydrogen sulphide odor. All this occurs in less than four hours. Without further oxidation the effluent from this tank would be a nuisance, and a detriment from the dilution standpoint.

The chief objection today to the use of septic tanks is that they may produce a nuisance, and may discharge sludge in hot weather when the ebullition is a maximum. For these reasons the separate digestion of the settled suspended matter is recommended, particularly in double-deck tanks of the Emscher type.

The septicity of a sewage is a point worthy of comment. If we assume that hydrogen sulphide is the proper index of the increase in septicity, the formation of insoluble ferrous sulphide might be accepted as a measure, provided enough iron were present in solution to combine with all of the hydrogen sulphide. The key to the question probably lies in the bacterial control of the septic tank process, but a far deeper knowledge of the species involved is required than we possess at present.

SLUDGE.

Whether sludge be fresh or old, its ultimate disposal has been and still is a problem for sewage experts. In order to fully appreciate the difficulties encountered in the commercial utilization of the product, it is necessary to consider its physical as well as its chemical composition. Fresh sludge is a black semi-liquid substance with an odor varying from that of burnt rubber to an acrid putrid stink. The specific gravity varies 1.01 to 1.06. In our case the grit chamber sludge frequently contains considerable quantities of heavier material, and its specific gravity may be as high as 1.35. The average quantity of moisture is from 85 to 95%, the percentage of organic matter 60, and of fixed matter 40, when calculated on a dry basis, in fresh sludge. The nitrogen on a dry basis amounts approximately to 2%, the fat varying from 1% to 5%.

Many schemes have been suggested for the utilization of

sludge as fuel, as filling for fertilizer and as material for gas, or even the manufacture of alcohol. Only in isolated cases under peculiar conditions has any process for the recovery of any by-products been successful. For instance in Bradford, England, where the sewage contains a deal of wash water from wool pulleries, fat has been successfully extracted from the sludge. The difficulty of the quick removal of the moisture from the sludge makes its use as a fuel doubtful. For the same reason drying the sludge for fertilizer purposes is uneconomical. Old sludge thoroughly digested contains much less volatile matter than the fresh sludge, the amount decreasing frequently from 60% to 40% of the total dry matter. In Germany and England, sewage sludge has been sold or given away to neighboring farmers, but the general experience has hitherto demonstrated the difficulty of disposing of sludge continuously in any such manner.

Partial purification of sewage can be accomplished under semi-aerobic conditions, as in a Dibdin slate-bed, which is akin to a contact bed. In this device nematode worms, infusoria, and bacteria accumulate and work over the sludge. Experience in this country with the slate beds has not been favorable.

CHEMICAL PRECIPITATION.

The colloidal matter in crude sewage may be eliminated by the use of chemicals as a precipitant. Ferric sulphate, aluminum sulphate, lime and ferrous sulphate have been frequently used in various combinations. The chemical to be employed and its quantity is largely governed by the composition of the sewage, and the cost of obtaining the chemicals. The quantity of sludge resulting is larger than from any other method of clarification. The effluent is low in suspended matter and is susceptible of treatment on filter beds at a high rate. Beyond a certain point, however, the application of chemicals does not reduce the amount of suspended matter appreciably. A concentrated sewage is better adapted to chemical clarification than a weak sewage.

COMPARISON OF METHODS.

More complete purification may be accomplished, either on intermediate sand filters, contact beds, percolating or trickling filters. The suspended and colloidal matter is mechanically retained by the filter material to be worked over by the biological life in the filter, which quickly forms in a new bed as a slimy coating on the surface of the particles of the filter material. The chemical change in the liquid is called nitrification or mineralization. When the bed becomes clogged, nitrification gradually ceases. In a sprinkling filter it is favored by the spraying of the liquid, which undoubtedly aids the oxidation process following. As a rule, more nitrates are formed in a sprinkling filter than in a contact bed, but less than in a sand filter.

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The deeper the writer progresses into the field of sewage disposal, the more he realizes the amount of work that is still required to make it an exact science or art. The co-operation of biologists, entomologists, chemists, and sanitary engineers is required. The sanitary chemist is mostly concerned with the investigations of the biologic features, a thorough knowledge of which will materially aid in bringing about a better understanding of the facts already accumulated, as well as the solution of new problems. For the industrial chemist, the most fertile field for investigation is the ultimate solution of the sludge question. At present we are able to reduce the quantity of the sludge to a minimum, and to prevent offense, but we realize that certain constituents, even though small in quantity, may some day prove of commercial service. The economies to be obtained, however, will be available only in large plants where careful operation is possible.

IN MEMORIAM

JOHN SANBORN METCALF, M. W. S. E.

Died March 4, 1912.

John Sanborn Metcalf, president of the John S. Metcalf Company and Member of the Western Society of Engineers since 1888, passed away at his home in Evanston, Illinois, on March 4, 1912. Of late years the rapidly developing business of the John S. Metcalf Company in grain-elevator designing and construction in Canada, had commanded a large amount of Mr. Metcalf's personal attention and many of his immediate friends, familiar with his long continued absence in connection with his business, were not aware of the serious condition in which he had been for several months previous to his demise.

Mr. Metcalf had been identified with grain-elevator operation and construction for over forty years, during which time he had been a powerful factor in the wonderful change and improvement

which has been made in such structures, and he advanced from an obscure position as operating foreman in an elevator at Indianapolis, to the foremost position in the profession.

Mr. Metcalf was a Canadian by birth, having been born March 7, 1847, at Sherbrook, Quebec, and came from an old New England family dating back to 1637. Michael Metcalf, the first paternal grandfather in America, came from Norwich in Norfolk County, England, and settled in Dedham, Massachusetts. Samuel Metcalf, the great grandfather of John S. Metcalf, served in the Revolutionary War, doing active duty first as minuteman and later re-enlisting at three subsequent dates for active participation in the struggle for independence. The Rev. Isaac Smith, a noted Congregational clergyman of Filmanton, New Hampshire, was the maternal grandfather of Mr. Metcalf. His father and mother, Lucian and Hannah (Smith) Metcalf, were reared in the southern part of Quebec Province near the state of New Hampshire, in an atmosphere from which he imbibed many of the sterling qualities which were characteristic of the old New England stock and has left its imprint indelibly upon its descendants.

Mr. Metcalf attended the public schools of his native town, and in 1870 came to the United States and located in Indianapolis, where he first became familiar with the operation and construction of grain elevators, having been engaged on the elevator "A" of that city and later managing it as its superintendent. A natural-born constructor, ever on the alert for the improvement and betterment of those things consigned to his care, it was but natural that he should grow to higher responsible duties and larger undertakings.

In 1881 he became superintendent of operation for the Burlington and Missouri River elevator at Burlington, Iowa, which position he held until 1887, when he came to Chicago, and with T. K. Webster and James Macdonald organized the Metcalf-Macdonald Company, for the designing and building of grain elevators. The business of the Metcalf-Macdonald Company developed rapidly and was continued until 1894, when the corporation was dissolved by mutual consent and Mr. Metcalf organized the present firm of John S. Metcalf Company, of which he was the head. The operations of the new concern immediately became an important factor in elevator building, both in the United States and abroad. Among the structures to the credit of the John S. Metcalf Company, are the Burlington elevator at St. Louis; Chicago, Burlington & Quincy elevator at East St. Louis; the Missouri Pacific at Kansas City; the Southern Pacific at Galveston; for the Grand Trunk Railway, one at Portland, Me., one at Tiffin, Ont., and one at Montreal, Que.; the Chesapeake & Ohio at Newport News, Va.; for the Manchester ship canal elevators at Manchester, England; the Canadian Pacific elevators at Victoria Harbor, Ontario, on the Georgian Bay; and the extensive conveyor system for the Harbors Commissioners of

Montreal. At present there is under construction a big 2,600,000 bushel elevator for the Harbors Commissioners at Montreal, and the 2,500,000 bushel elevator for the Canadian Pacific at Ft. William, Ont. Many of the latter buildings were erected of reinforced concrete, and are absolutely fireproof in their construction.

The John S. Metcalf Company conducted their Canadian business under a separate organization conforming to the laws of Canada. Mr. Metcalf's operations took him into all parts of the country, and the importance of his work placed him prominently in the front ranks of the engineers and elevator builders in America.

Mr. Metcalf was married December 25, 1873, in Indianapolis, to Miss Alice S. Richey, daughter of John and Charlotte (Millard) Richey, and a native of Marseilles, Illinois. Mr. Metcalf is survived by his wife and the following children: Terressa Adelia, who is the wife of C. C. Bonar, of El Paso, Illinois; Anne Maria, who is the wife of the Rev. P. E. Thomas, a Congregational clergyman of Somerville, Massachusetts, and Kate Lora. A son, Hugh Fred, died in infancy, anl Bertha Alice, who became the wife of John F. Strickler, died at Evanston, Illinois, in November, 1910.

Mr. Metcalf was a member of the Union League Club, Chicago Engineers' Club, Montreal Engineers' Club, the Canadian Society of Civil Engineers, the American Railway Engineering Association, and the Western Society of Engineers.

Mr. Metcalf was a man of splendid character and sterling integrity. He was modest, approachable and genial, kind hearted and accessible under all conditions. He maintained a very high standard of excellence in his work that gained him prominence, and he had reached his zenith of success at the moment when the ruthless hand was laid upon him. His funeral occurred Thursday, March 7th, and the interment was at Rosehill, Chicago.

James Macdonald,
C. S. Hall.
Committee.

JAMES PEARSON COLEMAN, ASSOC. W. S. E.

Died April 13, 1912.

James Pearson Coleman was born at Pemberton, Burlington County, New Jersey, August 31, 1849. He attended a preparatory school at Mount Holly, N. J., where he was prepared for the Rensselaer Polytechnic Institute and entered that institution in 1866. He would have graduated from there in the class of 1870 had not the death of his father, in November, 1869, caused him to feel it his duty to relieve his mother of the burden of his college expenses. He at once accepted a position as rodman in a party making a survey

for the Whitehall & Plattsburg Railroad, and for several years he was engaged in railroad location and construction in New York and New Jersey. From 1881 to 1884 he was assistant engineer on the construction of the Weehawken tunnel and terminal for the West Shore Railroad. Upon completion of that work he went to Chicago to engage in the introduction of the Otto gas engine through the West. In 1887 he again took up railroad engineering and was for several years connected with the Illinois Central Railroad Company on construction of the Chicago, Madison & Northern Railroad, and

JAMES P. COLEMAN.

on the location and construction of other Illinois Central lines in the West and South. Later he was division engineer on the Chicago & Northwestern Railroad, and for two years was with the Western Shipbuilding and Dry Dock Company at Port Arthur, Ontario. Last March, while engaged on work near Toronto, Canada, he was taken ill and sent to the hospital. Later, he was transferred to the Lakeside Hospital in Chicago, where he died—April 13, 1912. He became an Active Member of the Western Society of Engineers, March 5, 1890.

The preceding statement of facts regarding the life and pro-

fessional record of Mr. Coleman is necessarily too general to bring out fully the qualities that made him quite peculiar in some respects. The principal peculiarity that distinguished his entire professional life was his quiet but constant devotion to duty, not because it was duty but because it was an entirely natural thing to do.

No dangers of any nature, physical or human, held him back. With rioting all about him and threats of death thrown at him, he stood all day, alone, in a signal tower, handling the levers that moved switches and signals for passing trains in a congested yard and amidst confusing tracks. He simply had to do it because others were afraid and abandoned their post, and because he knew, as he had laid out the tracks, where the trains should go. It was this presence of duty to be done and an entire absence of fear that led him to move straight on with a survey across the lands of an irate land owner, though a shotgun was leveled at him.

These are but illustrations that emphasize the trait of character that made him one of the most reliable of men on difficult work. The hot suns of southern summers, the bitter cold of northern winters, the rugged pathless mountains, the jagged country—in fact, no obstacles of any nature stopped him when work was to be done. He did it all, bore all hardships and all dangers, with no thought of reward, or of appreciation even; he was satisfied just to do his work, and to do it accurately and well and on time. In these respects his life was heroic, the plane on which he moved was a lofty one, and yet so simple was his rule of life that he never knew how lofty was that plane.

His life is a beautiful example of the best sort for the younger men of his profession who wish to accomplish much and bravely, and though he probably never enunciated his rule of life, only lived it always, it was all comprehended in the following:

"Strive not for results, but to do one's duty and to build up character, our own and others', and to honor God and serve man."

Elmer L. Corthell,
William J. Karner.
Committee.

September, 1912

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Regular Meeting, September 2, 1912.

A regular meeting of the Society (No. 790) was held Monday evening, September 2, 1912. The meeting was called to order at 8:20 p. m. with Mr. A. Bement, First Vice-President, in the chair and about 35 members and guests in attendance.

The Secretary reported that at the meeting of the Board of Direction held June 27, the following applications for membership were presented:

George Lewis Mechem, Clarion, Iowa.
Harold Cooper Milnes, Evansville, Ind.
L. E. Dierks, Chicago.

Also that the following had been elected into the Society:

Ray Seely, Hammond, Ind........................Associate Member
Frank H. Cenfield, Chicago, transferred to..........Associate Member
Ralph M. Yager, Chicago........................Associate Member
George B. Mulloy, Chicago........................Associate Member
N. H. Jacobsen. Chicago, transferred to............Associate Member
George W. Phillips, Chicago........................Member
Robert S. Wallace, Chicago........................Junior Member

That at the meeting of the Board of Direction held August 2, the following applications were presented:

Henry Gratton Tyrrell, Evanston, Ill.
P. A. Poppenhusen, Chicago, transfer.
Henry M. Goodman, Honolulu, T. H.
John LeRoy Weber, Chicago.
Charles C. Wright, Chicago, transfer.

That the following had been elected into the Society:

David M. Wright, Chicago........................Junior Member
Robert J. Smith, Chicago, transferred to...........Associate Member
David H. Dugan, Chillicothe, Ill....................Member
Allen T. Kirk, Joliet, Ill..........................Associate Member
Louis E. Dierks, Chicago..........................Junior Member

and that at the Board meeting of August 30, the following new applications were presented:

Homer S. Baker, Marshfield, Wis.
Roy Shackleton, Chicago.
George W. Hand, Chicago.
Wm. H. Roney, Jr., Geneva, Ill., transfer.
Earl L. Wood, Chicago.

and the following applicants were elected into membership:

P. A. Poppenhusen, Chicago, transferred to.........Member
John L. Weber, Chicago............................Associate Member
Charles C. Wright, Chicago, transferred to..........Associate Member
Charles W. H. McKercher, Cuba...................Associate Member

The Secretary also reported that the Society had had two excursions during August. The first was to the hydro-electric plant at Keokuk, Iowa, now under construction, which was taken August 2-4 and where every attention was shown the visitors by Mr. Cooper, the chief engineer, and his assistants.

The second excursion was taken the afternoon of August 28 to the automobile factory of the Thomas B. Jeffrey Co., at Kenosha, Wis. Much attention was shown our party by the Jeffrey Co., and the excursion was greatly enjoyed by those who went.

There being no further business the Secretary read the paper for the evening by Mr. E. L. Corthell, M. W. S. E., "Brief Review of Engineering Practice and Personal Experiences in Latin America, 1880-1912."

After the reading of the paper Mr. Bement invited Prof. John F. Hayford to tell the meeting something of his recent work in the survey and locating of the boundary line between Panama and Costa Rica, to which he responded in an interesting manner.

The meeting adjourned about 10 p. m., when refreshments and cigars were served.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY

Sewage Disposal. By George W. Fuller. McGraw-Hill Book Co., New York. 1912. Cloth; 6 by 9 in.; pp. 767, including index. Illustrated. Price, $6.00 net.

In this book the aim has been to record the more important recent developments in the field of sewage disposal and to give the present status of both theory and practice, with comments drawn from the large experience of 25 years which the author has had in this specialty. Many valuable documents now out of print have been abstracted in order to illustrate the best available data on various topics. The book is written from the standpoint of the consulting engineer and is a compendium of theories and facts, rather than a guide to engineering designs and details. In this way it fills a very useful purpose and is a book which should be of the utmost value to every engineer and public official who comes in contact with the ever-increasing demand for the treatment of sewage.

The book is divided into four parts. The first covers the composition of sewage and the bacterial and bio-chemical processes active in the decomposition of sewage. The relation of oxygen to sewage purification as well as the question of odors is thoroughly taken up. The relation of the sewage bacteria to public water supplies and to shell-fish is covered at length.

In the second part of the book, American experience is thoroughly detailed on the problem of sewage disposal by dilution, not only in inland streams, but in large lakes, oceans and tidal estuaries. Suggestions are made on the most important ways for improving faulty conditions, copious reference being made to actual cases.

In the third part of the book various preparatory treatments of sewage are discussed, including screening, settling tanks, septic tanks, chemical precipitation tanks, electrolytical treatment and strainers. Particular stress is given to the discussion of septicization in two-story tanks. The relative merits of each device are plainly outlined as well as the question of the disposal of sludge. The notes on the electrolytical treatment are of particular interest.

The fourth part of the book deals largely with filtration, recording past experience as well as present practice not only in broad irrigation but in intermittent sand filters and the use of contact filters and sprinkling filters. Considerable space is devoted to a discussion of aeration, sterilization and ozonization processes as now understood. Such chapters are exceedingly interesting and should be profitable to any business man who is asked to contribute to fanciful schemes for the treatment of sewage. The final chapters cover institutional and residential plants. An excellent comparative summary of the whole field of sewage disposal is given.

In the text the distinction is clearly drawn between the methods which are thoroughly established and the unestablished methods, such as electrolytical treatment, strainers, slate beds and the like, as well as the wane of chemical precipitation and broad irrigation The author is extremely careful in his treatment to state impartially the facts and the weight of results obtained, so that his conclusions are shown to be thoroughly unprejudiced.

There is so much meat in the book that it is difficult to cover all the good points. Suffice it to say that if every sanitary engineer and health official owned and read a copy of the book there would be much less difference of opinion on many points where practice has been crystallized by the impartial judgment of specialists.—L. P.

Telephony. A Comprehensive and Detailed Exposition of the Theory and Practice of the Telephone Art. By Samuel G. McMeen and Kempster B. Miller. American School of Correspondence, Chicago. 1912. Cloth; 6¼x9½ in.; pp. 948, including index. Illustrated. Price, $4.00.

Probably no useful art, that has developed to the same magnitude, has produced fewer books in the process of its development than has the art of telephony. Applied telephony has not only preceded its literature, but it has frequently succeeded in eluding it. Practises described as standard in many an early book were often abandoned before the book had left the press; leaving the volume, with perhaps a value to the historian, but with little that might assist the practical telephone man in his daily work. Many of these earlier books were foreign publications, and were devoted to apparatus and methods utterly unknown in this country, and frequently unrepresentative even of foreign practice. This condition was most unsatisfactory for the student and the apprentice, for the trade is one that can be learned, in part, through books. Yet there was available only a meager and mistaken literature that was exceeded in value and in volume by that associated with trades that depend largely on technique, and but little on theory,—such trades as brick laying, boiler firing, tile setting, etc.,—a situation that left the apprentice to hunt for his education in the heterogeneous and confusing matter presented by the trade magazines; or to extract knowledge as best he could from a close-mouthed and unsympathetic confraternity.

However, the literature at hand for the student, and the apprentice, and the practical telephone man, has been steadily improving for some time, and McMeen & Miller's recent work, "Telephony," is the latest book to be published. While written in chapters that are connected and progressive, it is evidently the intention of the authors that the work shall be at once a text-book and an encyclopedia. To cover so much in only 927 pages necessitated the most judicious care in the selection and condensation of the vast amount of material at hand, and has resulted in a book that, among other good features, seems to be entirely free from padding of any sort. The thought is hazarded that while the book is eminently successful in its undertaking, it may be the last of the kind to be written in this inclusive form, for the accumulating mass of book matter relating to telephony would seem to make it necessary to limit the next work to a book of reference or to a book of education, and to abandon the idea of combining the two in one. The period of specialized books for the telephone man seems imminent. The next technical publication may be the second edition of Telephony; but it is more likely to be a treatise on spring jacks or on creosoted cross arms. In the meantime, the trade is fortunate in being able to obtain, between the two covers of one volume, so comprehensive a description of the industry, as it exists today in this country: and which description, in being prepared for all classes of readers, has maintained an excellent balance between generalization and specialization. So the book appears in most readable form, with a clear style, lightened at times by homely phrases that prevent the volume from being ponderous, except, perhaps, in physical weight. The illustrating of this book has been done in a very creditable manner; not only has the impossible problem of getting the page and the picture together, been well handled, but the familiar, cheap, and inexhaustible sources of pictorial supply, such as manufacturer's catalogues and patent office drawings, have been neglected; nor is use made of the patent office system of lettering and numbering—a system which may be illuminating to the legal mind, but which circuit men say is confusing. In their intention of providing a book for the man who knows nothing about the telephone business, as well as for the man who would add to his acquired knowledge, the authors have been altogether successful. If they have failed to provide for the third class—the man who knows

it all—it is because their long experience has taught them that he is in reality non-existent. E. H. B.

A Laboratory Manual of Physics and Applied Electricity. Arranged and edited by Edward L. Nichols, Professor of Physics in Cornell University. Vol. I. Junior Course in General Physics, revised and rewritten by Ernest Baker, Assistant Professor of Physics in Cornell University. The Macmillan Co., New York. 1912. Cloth; 6 by 9 in.; pp. 417, including index. 135 illustrations in the text, and 21 pages of tables. Price, $3.00 net.

The book opens with an introduction, with directions to the student on recording results, graphical representation of the same, errors of observation, etc. Chapter I relates to groups: A, Length, Time and mass; B, Statics; C, Friction; D, Uniformly Accelerated Motion; E, Moment of Inertia; and F, Elasticity. Chapter II takes up Group G, Density; and H, Properties of Gases. Chapter III treats of I, Calorimity; and J, Expansion. Chapter IV pertains to Group L, Lenses and Mirrors; and M, The Spectroscope, Gratings and the Spectrum. Chapter V, Group N, Photometry; and Chapter VI, Group O, relates to Sound. Next comes Chapter VII, Group P, Static Electricity; and Chapter VIII, Group Q, Magnetism. This is naturally followed by Chapter IX, Group R, Electric Current; Chapter X. S, Difference of Potential and Electro-Motive Force; and Chapter XI, Group T, The Measurement of Resistance. This is followed by Chapter XII, U, Electrical Quantity; and Chapter XIII, V, Electro Magnetic Induction. In conclusion, Chapter XIV, W, treats of the Magnetic Properties of Iron.

The book is well written, particularly for students. Though involving a great deal of mathematics, it presupposes that the reader possesses some knowledge of analytical geometry and the calculus, and has completed a course with text-book and lectures in the principles of physics. The book is the outgrowth of a system of Junior instruction extending over many years, but no attempt has been made to include the whole of physics. The principle has been followed of introducing only such experiments as have been in actual use. This manual has been designed primarily for those students who are preparing themselves to become engineers. It is hardly necessary to say that coming from the Macmillans, the paper, typography, and illustrations, as well as the character of the writing, are first class in all particulars. W.

Non-Euclidean Geometry. A Critical and Historical Study of Its Development. By Roberto Bonola, Professor in the University of Pavia. Authorized English translation, with additional appendices, by H. S. Carslaw, Professor in the University of Sydney, N. S. W., with an introduction by Federigo Enriques, Professor in the University of Bologna. Open Court Publishing Co., Chicago. 1912. Cloth; 5 by 7½ in.; pp. 268. Price, $2.00.

For simplicity and elegance of treatment of a subject which was a source of confusion to mathematicians for centuries, Roberto Bonola's "Non-Euclidean Geometry" leaves little to be desired. The English translation, by H. S. Carslaw, now renders this little book accessible to an extensive class of readers. The fact that, except in the last chapter and the appendices, no knowledge of mathematics beyond elementary geometry and trigonometry is required for a complete understanding, gives this work, I believe, a unique place among treatments of this subject. A willingness to study carefully the first 128 pages is all that is necessary for an introductory knowledge of one of the most interesting developments in mathematics during the last century.

The subject is taken up mainly in the order of historical development, beginning with the attempts of the Greeks and Arabs to prove Euclid's famous Fifth Postulate, and tracing the history of this postulate and the

theory of parallels until it was finally shown that postulates which contradict the Fifth Postulate may be used as a basis for a logically consistent geometry. Three such (Non-Euclidean) geometries are given particular attention. Numerous references to the literature of the subject make the book particularly valuable to the thorough student of geometry.

E. J. MOULTON.

LIBRARY NOTES

The Library Committee desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

McGraw-Hill Book Co.:
Sewage Disposal, George W. Fuller. Cloth.
The Design of Mine Structures, M. S. Ketchum. Cloth.
Cleveland Engineering Society:
Progress Report of the Ohio Co-Operative Topographic Survey, to January 1, 1910. Cloth.
New Hampshire Public Service Commission:
Annual Report, 1911. Cloth.
John C. Trautwine, Jr.:
Trautwine's Civil Engineer's Hand Book, 1911. Leather.
Concrete, Trautwine. Cloth.
Wm. J. Baldwin, Jr.:
Quick Rules for Heating and Ventilating. Baldwin. Cloth.
Pittsburg Flood Commission:
Report of Pittsburg Flood Commission. Cloth.
National Rivers and Harbor's Congress:
Proceedings of Eighth Annual Convention, 1911. Cloth.
Leonard Metcalf:
Some Fundamental Considerations in the Determination of a Reasonable Return for Public Fire Hydrant Service. Pam.
American Telephone and Telegraph Co.:
Telephone Statistics of the World. Pam.
Norman W. Henley Publishing Co.:
Diary of a Round House Foreman. T. S. Reilly. Cloth.
John Wiley & Sons:
Electrical Injuries, Dr. C. A. Lauffer. Cloth.
E. E. R. Tratman, M. W. S. E.:
Illinois Railroad and Warehouse Commission, Reports for 1908-9-10.
Index to Signal Literature, Vol. I. Cloth.
Baltimore Harbor Board, Annual Report, 1910. Pam.
Montreal Harbor Commissioners, Annual Report, 1909. Pam.
International Congress of Street and Local Railways, Brussels, 1910.
R. G. Thwaites, Madison, Wis.:
Blue Book of Wisconsin, 1911. Cloth.
Bion J. Arnold, M. W. S. E.:
Third Annual Report of Board of Supervising Engineers, Chicago Traction. Cloth.
Anson Marston, M. W. S. E.:
Graduates of Division of Engineering, Iowa State College. Cloth.
Roderick McColl:
Report of Subsidized Railways and Other Public Works, Province of N. S., 1911. Pam.
McGraw-Hill Book Co.:
Practical Descriptive Geometry, W. G. Smith. Cloth.
Reinforced Concrete Construction, G. A. Hool. Cloth.

Highway Engineers' Handbook, Harger and Bonney. Leather.
Reinforced Concrete Buildings, Ransome and Saubrey. Cloth.
Freight Terminals and Trains, Droege. Cloth.

J. B. Lippincott Co.:
Machine Design; Hoists, Derricks and Cranes. H. D. Hess. Cloth

B. F. Affleck, M. W. S. E.:
The Official Good Roads Year Book, 1911. Cloth.

C. L. Strobel, M. W. S. E.:
Banking Reform, J. L. Laughlin. Cloth.

EXCHANGES.

American Institute of Electrical Engineers:
Year Book, 1912. Cloth.

Canada Department of Mines, Mines Branch:
Annual Report of the Mineral Production of Canada for 1910. Pam.

Iowa Engineering Society:
Proceedings, 24th Annual Meeting, 1912. Pam.

Engineers' Club of St. Louis:
17th Annual Bulletin, 1912. Pam.

Wisconsin Railroad Commission:
Various Opinions and Decisions. Pams.

Pennsylvania State Commissioner of Health:
Annual Report, 1909, Parts I and II. 2 vols.: cloth.

Illinois Society of Engineers and Surveyors:
27th Annual Report, 1912. Pam.

John Crerar Library:
17th Annual Report, 1911. Pam.

Metropolitan Sewerage Commission of New York:
Preliminary Report on Disposal of New York's Sewage. Pam.

New York Public Service Commission, First District:
Annual Report, 1910, Vols. I and II. Cloth.

National Rivers and Harbors Congress:
Proceedings, 1907, 1909. 2 cloth.

Canadian Society of Civil Engineers:
Report of Annual Meeting of 1912. Pam.
Transactions, October-December, 1911. Pam.

Engineering Association of the South:
Proceedings, April-June, 1912. Pam.

Chicago Department of Electricity:
Annual Report, 1911. Cloth.

American Institute of Mining Engineers:
Transactions, 1911. Paper.

Providence, R. I., City Engineer:
Annual Report, 1911. Pam.

Boston Society of Civil Engineers:
Year Book, 1912-13. Pam.

Metropolitan Water and Sewage Board, Boston:
Eleventh Annual Report, 1911. Cloth.

Engineering Association of New South Wales:
Proceedings, 1909-10. Cloth.

Maine Commissioner of Highways:
Seventh Annual Report, 1911. Cloth.

Institution of Water Engineers, London:
Transactions, 1911. Cloth.

American Electrochemical Society:
Transactions, 1912. Pam.

Rhode Island Commissioner of Dams and Reservoirs:
Annual Report, January, 1912. Pam.

New Orleans Sewerage and Water Board:
 24th Semi-Annual Report, 1911. Pam.
New York Barge Canal Terminal Commission:
 Report, 1911, Vols. I and II. Cloth.
Society for the Promotion of Engineering Education:
 Proceedings, 19th Annual Meeting, 1911. Cloth.
Milwaukee City Engineer:
 Annual Report, 1911. Cloth.
Brooklyn Engineers' Club:
 Proceedings, 1911. Cloth.
Chicago Builders' Association:
 Directory, 1912. Leather.
Baltimore Sewerage Commission:
 Annual Report, 1911. Paper.
New Jersey State Board of Health:
 Annual Report, 1911. Cloth.

GOVERNMENT PUBLICATIONS.

U. S. Geological Survey:
 The Production of Fuller's Earth in 1911. Pam.
 Production of Sulphur, Pyrite, and Sulphuric Acid in 1911. Pam.
 Production of Phosphate Rock in 1911. Pam.
 Geological Folios Nos. 177, 178 179, 180, 181, 182.
U. S. War Department:
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MEMBERSHIP

Additions.

Cenfield, F. H., Chicago, transfer, Junior to.............Associate Member
Dierks, Lewis E., Chicago.................................Junior Member
Dugan, David H., Chillicothe, Ill.................................Member
Jacobsen, N. H., Chicago, transfer, Junior to...........Associate Member
Kirk, Allen T., Joliet, Ill.............................Associate Member
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Mulloy, George B., Chicago..............................Associate Member
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Wallace, Robert S., Chicago...............................Junior Member
Weber, John L., Chicago.................................Associate Member
Wright, C. C., Chicago, transfer, Junior to.............Associate Member
Wright, David M., Chicago.................................Junior Member
Yager, Ralph M., Chicago................................Associate Member

Deaths.

Charles Wesley Brown, Jacksonville, Ill......................May 25, 1912
Charles Edward DeCrow, Chicago..............................June 17, 1912

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GEOLOGY, MINING AND PREPARATION OF ANTHRACITE

H. H. Stoek,* M. W. S. E.

Presented June 3, 1912.

Anthracite is defined by the Standard Dictionary as "Mineral coal with a bright sub-metallic iron black lustre, conchoidal fracture, and a very small amount of volatile matter; in popular usage hard coal. It consists of nearly pure carbon and burns almost without flame."

The distinguishing features between hard coal, or anthracite, and soft, or bituminous, coal to non-professional users is the absence of smoke and flame when the former burns, and the fact that it is much cleaner to handle.

The general properties of anthracite are briefly as follows:

Composition: The variations in composition of twenty-nine analyses from different sections of the anthracite region by Mr. A. S. McCreath are:

Water	3.00% to 4.11%
Volatile Matter	3.08% to 4.38%
Fixed Carbon	87.98% to 80.86%
Sulphur	0.46% to 0.73%
Ash	4.38% to 11.23%
Specific Gravity	1.57% to 1.66%

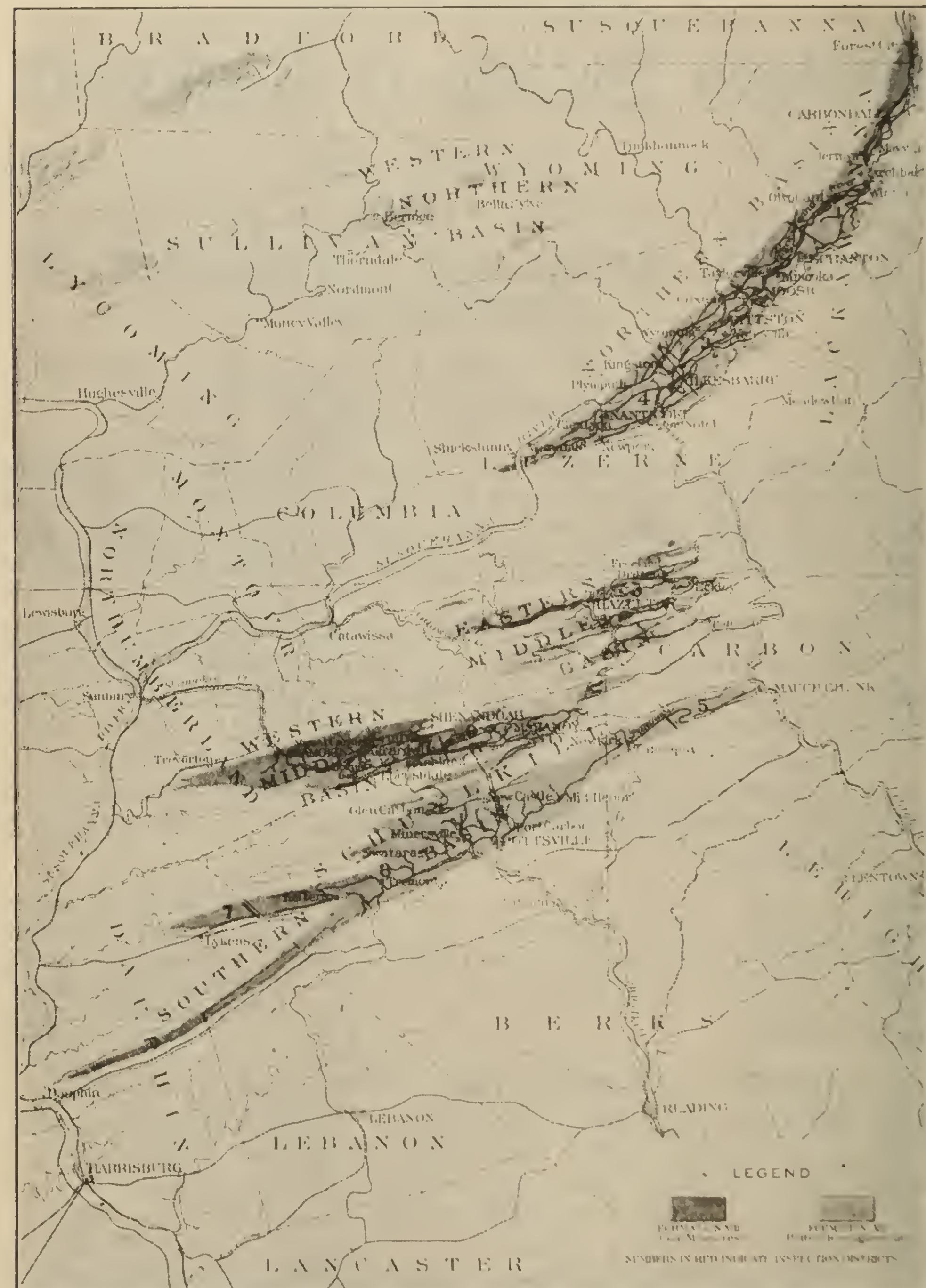
Anthracite is now cleaned more perfectly than it was when the above analyses were made, and a series of analyses made now would probably show the average coal shipped to market at present to be somewhat purer than that given in the above table.

Although the lustre of anthracite has a decided effect upon its selling value, it is not an indication of either good or bad qualities in the coal, and a dull anthracite may have more heat value than a bright and glossy coal. It is difficult, however, to convince the ordinary retail purchaser of this fact.

Anthracite from different sections and from different seams

*Professor of Mining Engineering, University of Illinois.

in the same section may vary quite considerably in composition and in specific gravity. It is commonly assumed that the specific gravity



Pennsylvania Anthracite Coal Field.

is 1.5. In most calculations this is sufficiently accurate, but where great accuracy is required, a determination should be made for the particular coal in question.

Although anthracite is mined in small quantities in other parts of the United States than Pennsylvania, these amounts are so small compared with the production of the greater field that no attention will be paid to them in this paper, and all references to the anthracite field will apply to the small district in northeastern Pennsylvania, which, broadly speaking, is bounded on the west by the Susquehanna River, on the north by the north branch of the Susquehanna River, on the east by the Delaware and Lehigh Rivers, and on the south by a line extending from Mauch Chunk to Harrisburg. This district embraces a territory of about 3,300 square miles, but less than one-fifth of this total area, or about 484 square miles, is underlain by workable coal measures. This productive portion is, moreover, not a continuous area, but consists of a number of detached valleys or basins as shown on the accompanying map. This area is divided into three sub-divisions from the trade standpoint, the Wyoming, the Lehigh, and the Schuylkill regions. Geographically, and in a broad sense, geologically, the field is divided into four parts, the northern, containing 176 square miles, the eastern middle containing 133 square miles, the western middle containing 94 square miles, and the southern middle containing 181 square miles. The Wyoming and the northern fields are the same, while the Schuylkill region includes approximately the western middle and the southern.

From the standpoint of the labor organization, The United Mine Workers of America, the region is divided into three districts: No. 1, corresponding to the Wyoming region, No. 7, corresponding to the Lehigh region, and No. 9, corresponding to the Schuylkill region.

The daily newspapers, with periodic regularity, have accounts of new anthracite fields discovered, the favorite districts for such discoveries being the Pocono Mountains, between the Wyoming region and the Delaware River, the Nescopeck Valley situated between the Wyoming and Lehigh regions, and the region north of the Wyoming Valley and south of the small outlying patch of semi-anthracite known as the Loyalsock basin. The geologic features of the region are, however, so well known, and so much prospecting work has been done by the Second Geological Survey of Pennsylvania and by the large mining corporations, that the limits of the anthracite measures are now approximately known, and it is improbable, though of course not impossible, that new districts will be discovered.

Geologically, Pennsylvania anthracite all belongs to the carboniferous period, and, according to Leslie, these beds were originally bituminous in character and deposited at the same time as the bituminous beds of western Pennsylvania.

A very striking feature of the anthracite coal field is the basin-like form of the present measures, the remnant of the original deposit remaining in place after the erosion due to passage of the

glacier, being in the form of a canoe with the coal outcropping usually on the hillsides enclosing the valleys or basins.

The coal beds are frequently upturned to a vertical position, and sometimes even overturned. At the upper or northeast end of the northern field the basin slopes in gentle curves, which gradually increase in steepness toward the southwest and west, and at the lower end of the field, in the neighborhood of Glen Lyon, the measures dip steeply and are very much contorted. The general dips in the northern field are much more gentle and uniform than in any of the other fields.

In the eastern middle field the basins are shallow, but the dips are sharp, being from 30° to 50° and even more.

The basins of the western-middle and southern are deep, with steeply dipping sides, the maximum of depth and steepness being in the southern field.

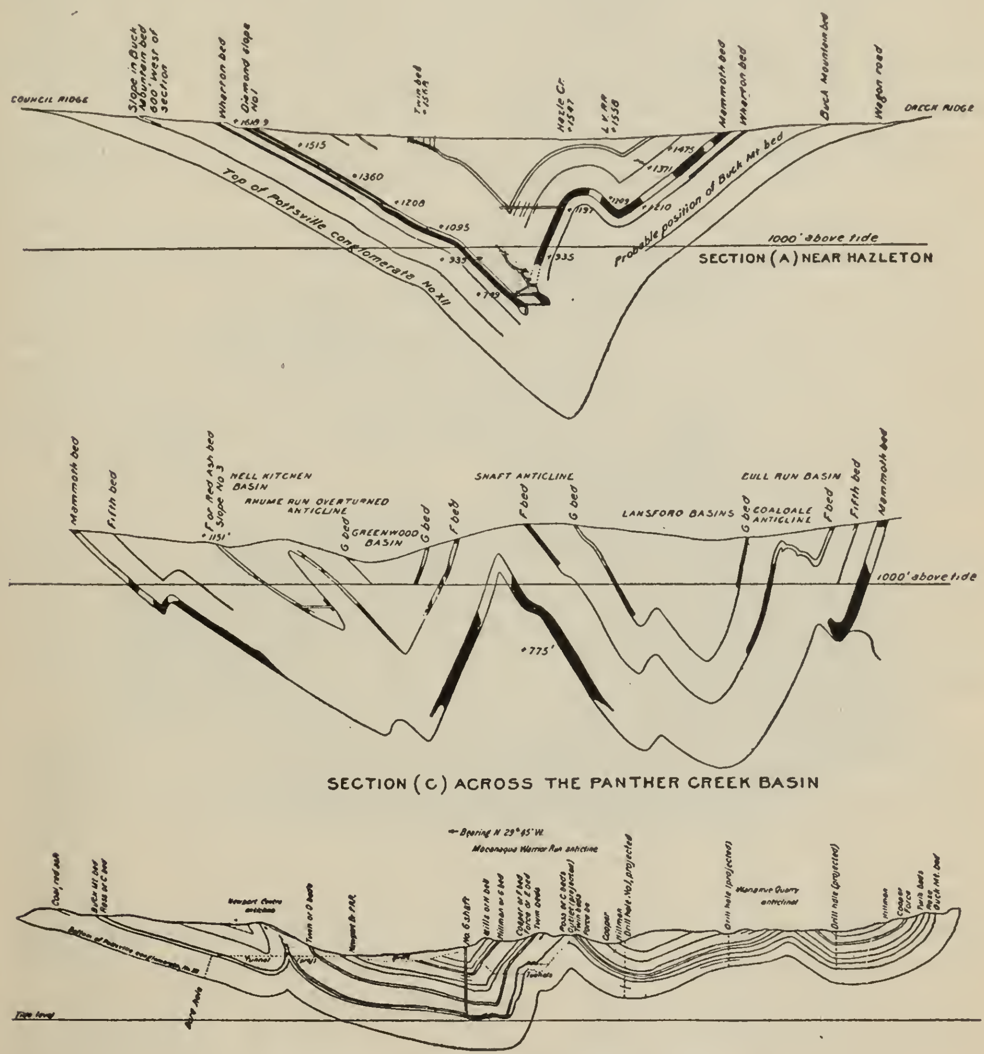
Throughout all of the fields the steepest dips are, as a rule, toward the north, and the more gentle ones toward the south. These characteristics are well shown in the accompanying cross-sections of the several fields.

Just what part of the original deposits of anthracite the present fields represent we have no way of telling, for during the glacial period undoubtedly a vast amount of coal was swept away, and only that portion in the deeper valleys was left. Various estimates have been made that the remnant represents only from 1 to 6 per cent of the original deposit, but such estimates are purely hypothetical.

Within the anthracite basins the Second Geological Survey of Pennsylvania recognizes but two formations or horizons, the Pottsville Conglomerate, or No. 12, and the Coal Measures, or No. 13.

The Pottsville Conglomerate consists of beds of gray conglomerate sometimes with fairly large nodules, white, gray and brown sandstones, which are usually coarse and hard; thin beds of carbonaceous slates; and usually one or more thin beds of coal. These coal beds increase in thickness and value from northeast to southwest, and while they are not usually workable in the Wyoming region, in the western part of the southern and western middle regions there are large, valuable and workable beds. The lower strata of the conglomerate are greenish in color, gradually shading down into the red of the underlying Mauch Chunk red shale. The central portion of the formation is coarse and hard, and forms the crest of the mountain regions enclosing the coal basins. The conglomerate changes in character from northeast to southwest. In the extreme northeast part of the region northeast of Scranton, coarse sandstones and fine conglomerate predominate, but going toward the southwest the size of the pebbles gradually increase until in some instances they become distinct boulders. The known maximum thickness of the conglomerate is 1,475 ft. at Kalmia Colliery. In the northern basin it is 225 ft., eastern middle, 300 ft., western middle, 850 ft., and in the southern, 1,200 ft.

The maximum thickness of the coal measures remaining and overlying the conglomerate is, northern field, 1,800 ft., eastern middle, 700 ft., western middle, 1,000 ft., and southern, 2,500 ft. The Coal Measures include beds of sandstone, coal, shale and fireclay, underlain by the Pottsville Conglomerate. No correlation of the measures between the anthracite and bituminous regions of Pennsylvania has yet been worked out, nor is it certain that one ever can be.



SECTION (D) SOUTH OF NANTICOKE

Cross Sections of Anthracite Coal Field.

Coal beds are distributed throughout the whole extent of the formation, the beds varying in thickness from a mere trace up to the Mammoth bed, which has a thickness of from 50 to 60 ft. over wide areas. The total thickness of workable coal is 70 to 113 ft., approximately 100 ft. As a general rule, the lower 300 to 500 ft. of the Coal Measures up to the top of the Mammoth contain the

thicker deposits. The beds are separated by intervals varying from a few feet to several hundred feet, and a barren interval of 200 ft. is rare. The rocks intervening between the coal beds may be classified as follows: (1) Brown or gray sandstone, varying in texture from soft and shaly up to coarse and hard, and merging into fine conglomerates, which, in some instances, are so coarse as to be mistaken for the Pottsville Conglomerate. (2) Shales of various degrees of hardness and varying in color. (3) Black, carbonaceous slate or shale. (4) Fire clays, frequently, but not always, underlying the coal, and also frequently found apart from the coal beds. The intervals between the same coal beds vary greatly in different basins, and even in different parts of the same basin.

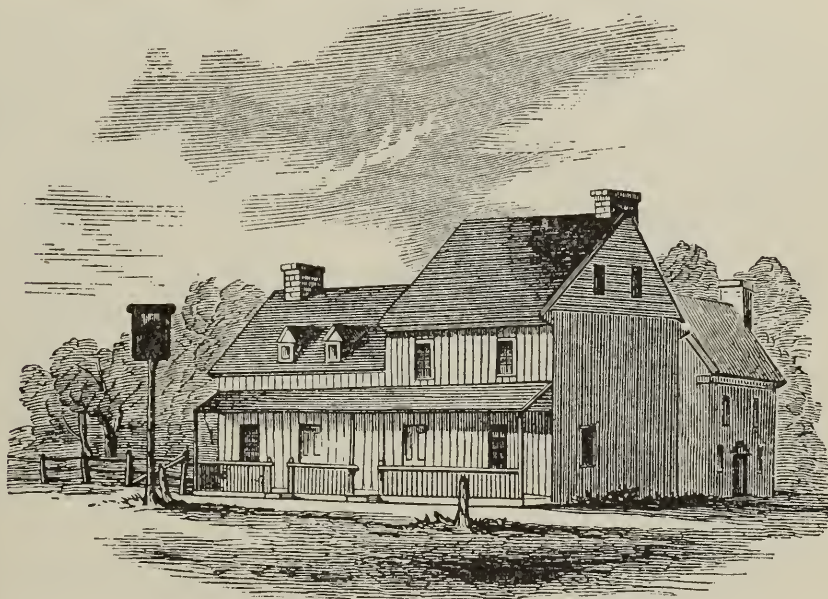
In the northern field different names are given to the same bed in different sections, but in the eastern middle, western middle, and southern basins common names are used, at least for the principal coal beds, which are quite similar in these three districts, so that the measures can be correlated with comparative ease. No successful attempt has yet been made to correlate all of the beds of the northern field with those of the other fields, although the Red Ash, Skidmore, and Baltimore beds of the northern field are generally accepted as being identical with the Buck Mountain, Skidmore, and Mammoth beds, respectively, of the southern and middle fields.

Although there are certain features which are more or less common to the important beds throughout a district, their local variations are so marked as to render it impossible, in so condensed a description as the present, to give characteristic features, for descriptions would have to be so generalized that they would probably be misleading.

History: The early history of anthracite is legendary and closely connected with the Indian stories which play so prominent a part in most of our American history. As there are numerous outcropping beds of anthracite in each of the different regions already noted, it is probable that its presence, and possibly its use, were known to the Indians before the advent of the white man in northeastern Pennsylvania. The first authentic date, however, in connection with anthracite, is 1762, when Parshall Terry and a company of Connecticut pioneers found coal at the mouth of Mill Creek on the banks of the Susquehanna, near the site of the present city of Wilkes-Barre. In 1769, Obadiah Gore, a blacksmith, used anthracite fuel in his forge at Wilkes-Barre, and this is the first use to which anthracite was put in nearly all of the districts in which it was discovered subsequently. In 1775, the proprietary government of Pennsylvania had coal floated down the Susquehanna from Wilkes-Barre to Harris Ferry (Harrisburg), whence it was hauled by wagons to the arsenal at Carlisle for use in the manufacture of munitions of war. The interval between 1762 and 1800 may be said to be the period of discovery, as during that time most of

the important fields were found, though, of course, not fully explored.

From 1800 to 1820 is a second distinct period in this history, and during that time strenuous efforts were made to show people that it was usable as a fuel. Hand bills were printed in English and German and distributed broadcast, pointing out the merits of the new fuel, and describing in detail the method of burning it. Certificates from blacksmiths who had used it were distributed, and journeymen were bribed to buy it. Charcoal became scarce about this time, and on account of the war of 1812, it was difficult to procure coal from Virginia. Both of these causes offered an inducement to burn anthracite. Shippers of fuel accompanied their shipments of coal and gave demonstrations in New York and



Exterior of Fell House.

Philadelphia of the method of burning it, and it was not until about 1820 that anthracite had won for itself a permanent place as a fuel.

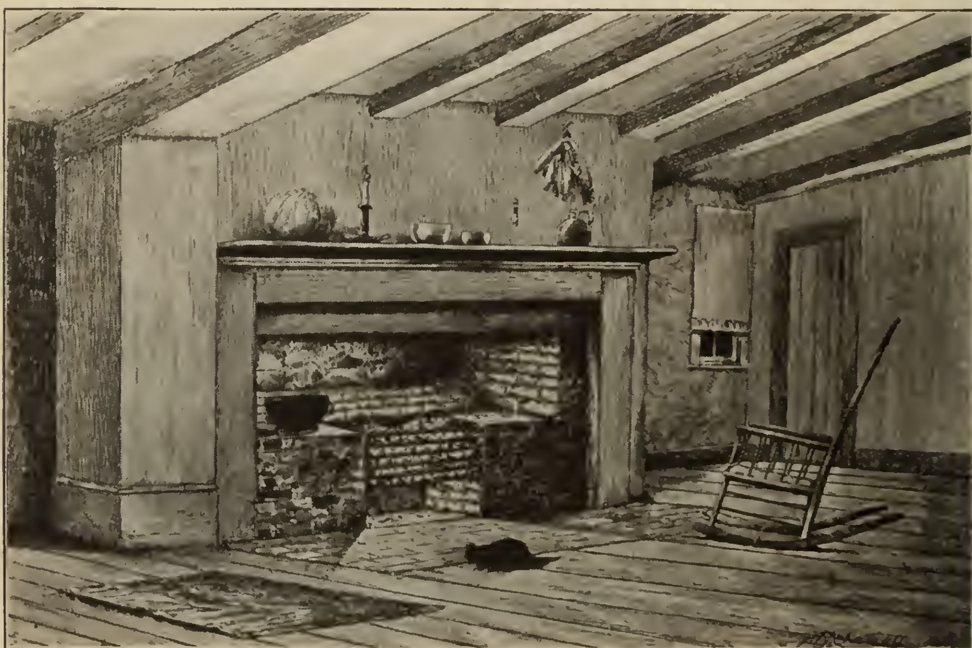
Oliver Evans and Frederick Groff burned anthracite in a grate in Philadelphia, in 1802, but entirely independent of them and without knowing that they had accomplished this, Judge Jesse Fell succeeded in burning it in a grate in Wilkes-Barre in 1808, and a report of his experiment is to be found on the fly leaf of a "Treatise on Masonry" in the form of the following entry.

"Feb. 11th, 5808 of Masonry. Made the experiment of burning the common stone of this valley in a common fireplace in my house, and find it to answer the purpose of fuel and making a clear and better fire at less cost than burning wood in the common way."

Letters from Judge Fell which are preserved by the Wyoming Historical Society of Wilkes-Barre corroborate the above memoran-

dum and give greater details in regard to it. The old Fell house was destroyed in April, 1905, but the grate still remains. The restored grate as shown is probably not like the original one, which consisted mainly of iron bars laid across the bricks and upon which the coal was laid instead of being in the basket form commonly shown.

The history of the coal trade does not begin with the year 1820, as most authors state, for in 1805 and 1806, John and Abijah Smith from Derby, Conn., settled in Plymouth, Pa., and immediately began shipping coal to points along the lower Susquehanna. Fifty-five tons were shipped in 1807, to Columbia, Pa., and thereafter 400 to 500 tons were sent yearly to ports on the lower Susquehanna and to Baltimore, where $10.00 per ton was received, while $12.00



Interior of Fell House, Showing Grate.

per ton was received in New York. The coal was shipped in timber arks which were broken up and sold for lumber, only the iron parts being returned for use in making other arks. The decade from 1820 to 1830 can be called the period of river navigation, for by the latter year a number of canals were in operation, and these, together with the gravity roads, superseded the river navigation. In spite of the introduction of steam roads for transporting coal, canals and gravity roads remained a factor for over seventy years, and it was not until the beginning of the twentieth century that they were entirely abandoned.

Method of Mining: In speaking of the basin formation of the anthracite deposits, attention was called to the fact that in many cases the beds out-crop along the hillsides. It is frequently

possible, in such cases, to remove the over-burden with the steam shovel, and to take out the underlying coal by open work. The Mammoth seam which is from 40 ft. to 60 ft. in thickness, and sometimes even more, lends itself admirably to this system of mining, and the very extensive strippings are found in the Lehigh and Schuylkill regions, and occasional but less extensive ones also in the Wyoming region.

The room and pillar method of mining is the one generally used; several experiments have been made with long wall, but scarcely as yet upon a commercial scale. Owing to the irregularity

Anthracite Stripping.

of the coal measures, the room and pillar method cannot be as regularly laid out as it is often possible to do in bituminous workings.

Many of the earlier mines were opened by drifts, but at present shafts and slopes predominate as means of reaching the workings. Where the pitch of the seam is small, say from 3° to 10°, the rooms (or breasts as they are called in the anthracite field) are turned off at such an angle with the entry (or gangway, as the entries are generally called in the anthracite field) that the inclination of the track in the room is such that the car can be taken

to the face by a mule, and run out by gravity. When the pitch is too steep, say about 10°, the rooms are turned off at right angles to the gangways. For inclinations from 10° to 18°, that is, when mule haulage is impossible, and before the inclination is such that the coal will slide on a sheet-iron chute, a small car called a "buggy" is used. These are loaded at the face and are then pushed by hand along a track which is built up so as to decrease the grade to the foot of the room, where the coal is dumped upon a platform and shoveled thence into a mine car.

When the pitch is between 18° and 30°, chutes of sheet-iron are placed on the bottom and the coal shoveled down these to a platform at the bottom or directly into a mine car.

At a greater inclination than 30°, the coal will slide on the bottom without the use of sheet-iron, and a stopping or "battery" is placed at the bottom to check and hold back the broken coal.

Method of Working an Anthracite Mine.

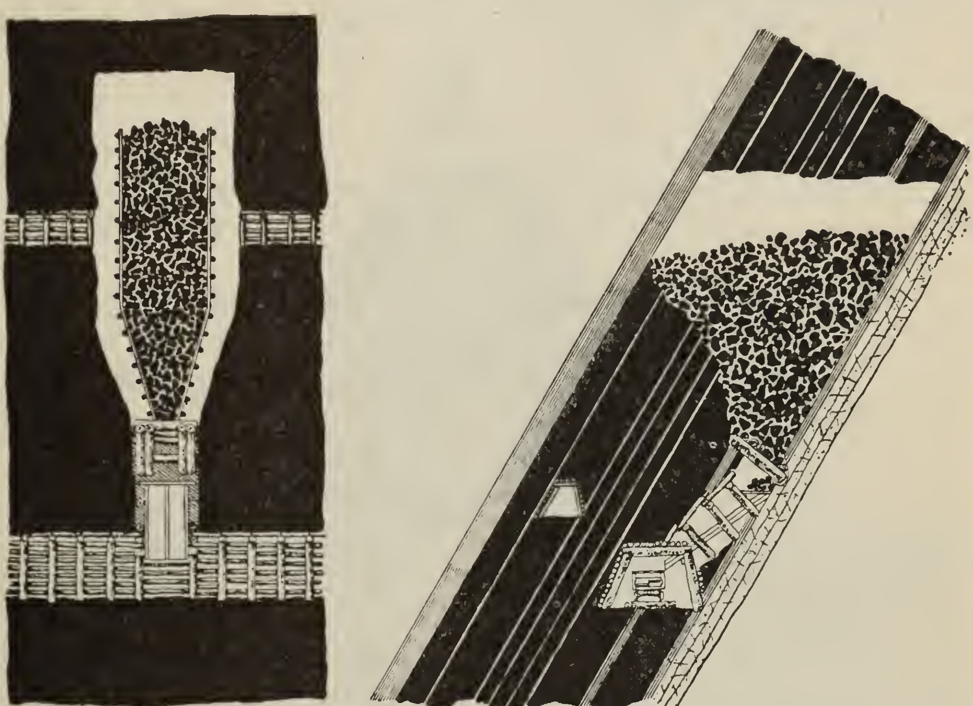
These batteries are built of logs or heavy planks, and the broken coal piles upon them up to within a short distance of the face; only enough coal being drawn out from the center or from the sides of the battery to keep the top of the broken coal at a sufficient distance from the face, so that the miner can stand upon this broken coal and work at the face.

If the coal bed is more than 6 or 8 ft. in thickness, it is usually mined out in two or more benches.

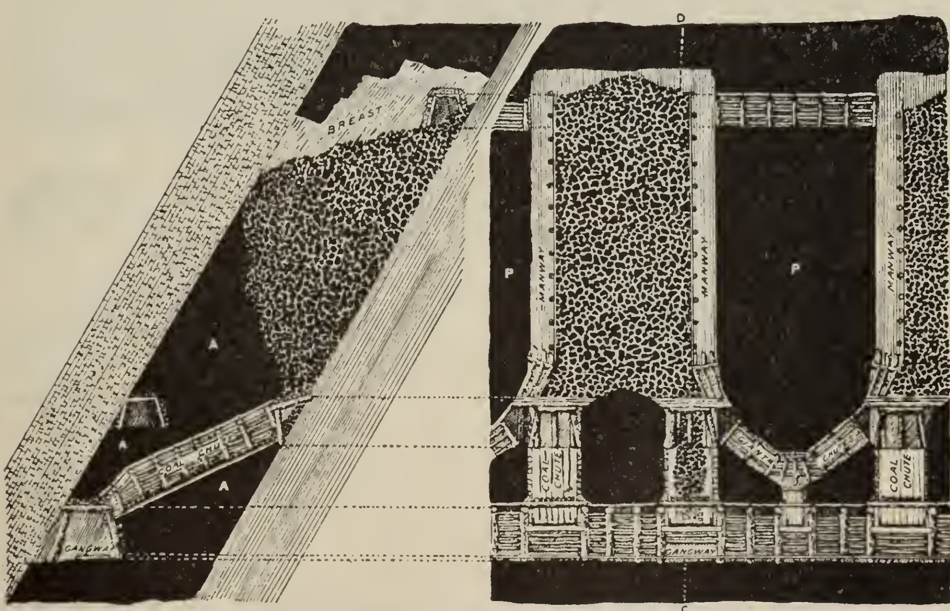
Drilling is usually done by hand, though electric motor drills have been tried and found to be practicable. Under-cutting with the chain machine has been tested, but never adopted upon a commercial scale, although preliminary tests indicate that the method is applicable in the anthracite field. Until comparatively recently, black powder was the common explosive, and large quantities of unglazed powder were used. In the gaseous mines large quantities of dynamite and permissible explosives are now being used to a considerable extent. Marsh gas is found in many of the deeper

mines, particularly in those of the Wyoming and the western end of the Schuylkill regions. A number of mines are worked entirely with safety lamps.

The mines are universally ventilated by rotary fans, usually of



—Method of working breasts on the Mammoth bed at Hazleton, No. 6 colliery of A. Pardee & Sons.



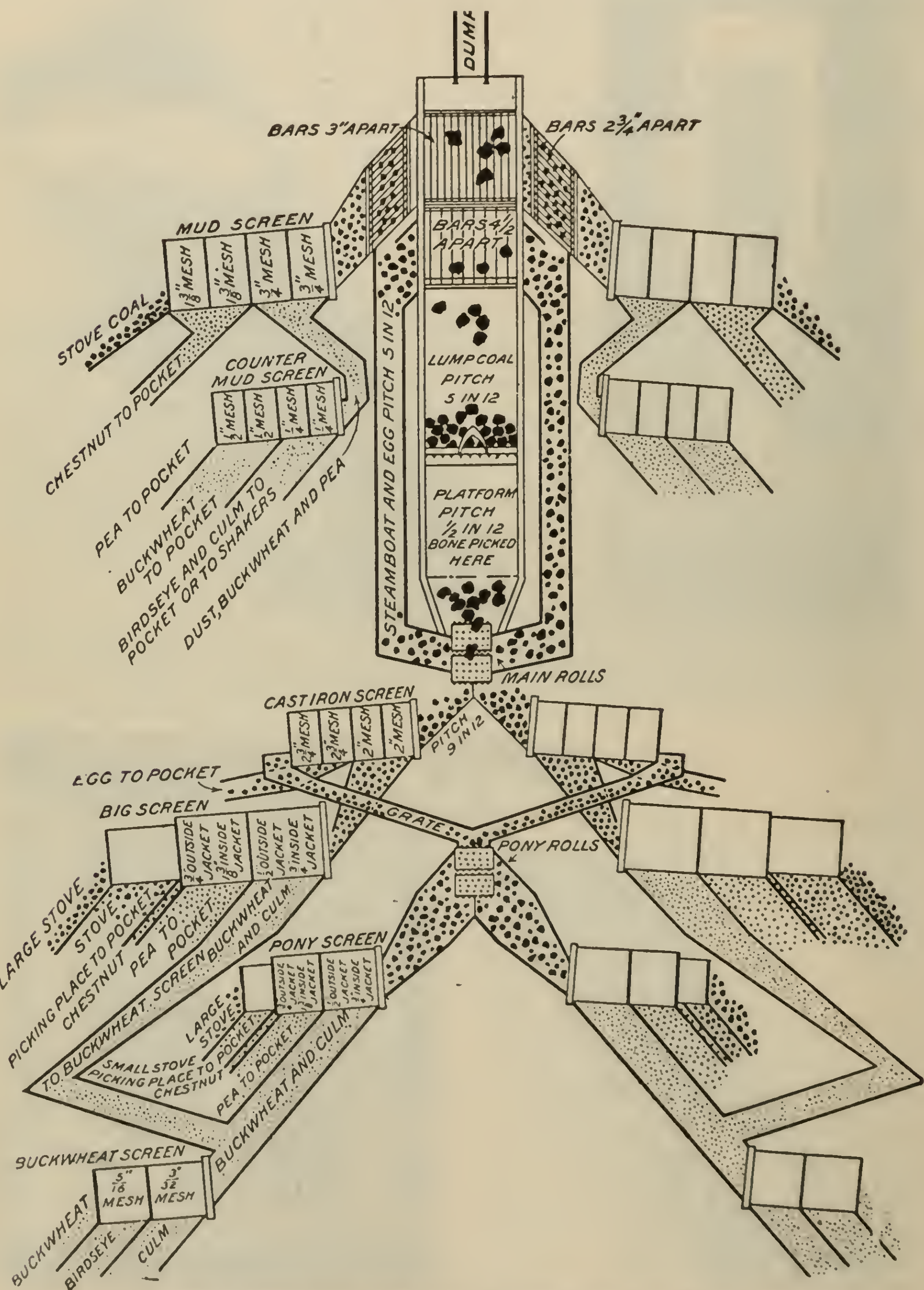
—Double-chute breasts, with batteries; steep dip.

Methods of Mining in Inclined Workings.

a modified Guibal or Capell type. While closed fans are generally used, a number of open fans are still running.

Every known form of haulage is in use in the anthracite region, and the first use of electric mine locomotives in America was at Lykens, Pennsylvania, in 1887.

Run of mine anthracite cannot be marketed as it comes from



-Breaker diagram, showing method of preparing anthracite coal for market

Preparation of Anthracite.

the mine, or even after the comparatively simple screening process to which bituminous coal is ordinarily subjected. The economical combustion of anthracite requires the pieces to be as nearly as possible of uniform size, and the greatest market demand is for intermediate sizes commonly used for domestic purposes, viz.: chestnut, stove and egg. The large sizes as they come from the mine are usually broken down to form the smaller sizes. The elaborate preparation to which anthracite is subjected increases the cost of the coal to the consumer, for two reasons: First, the actual cost of the preparation, and second, the fact that there is considerable loss in value in breaking down the coal, as the fine coal does not command as high a price as the coarse. The crushing

Truesdale Washery and Breaker.

is done by ordinary toothed rolls and screening is carried on in either revolving or shaking screens. The slate is picked from the coal either by boys and old men, or by automatic pickers of which there are a number now operating.

A number of the breakers more recently built have a capacity of 4,000 tons per day, and the cost of a modern breaker is $150,000 upward. Until recently they were usually built of timber, but there is a constantly increasing use of steel. Within a few years concrete has been largely used up to the screening floor.

A great change has taken place in recent years in the relative amounts of the different sizes of anthracite used. The production of the sizes above grate size has been largely discontinued, while the amount of pea and smaller sizes has increased enormously.

October, 1912

The sizes of anthracite are not absolutely fixed, but the following table gives screen perforations that are probably as near an average as can be obtained:

Lump over bars placed 7 to 9 in. apart.

Steamboat over bars placed 3½ to 5 in. and through bars placed 7 to 9 in. apart.

Broken or grate passes over 2¾ in. mesh and out of end screen.

Egg passes over 2 in. mesh and through 2¾ in. mesh.

Stove passes over 1⅜ in. mesh and through 2 in. mesh.

Chestnut passes over ¾ in. mesh and through 1⅜ in. mesh.

Pea passes over ½ in. mesh and through ¾ in. mesh.

Buckwheat No. 1 passes over ¼ in. mesh and through ½ in. mesh.

Buckwheat No. 2 passes over ⅛ in. mesh and through ¼ in. mesh.

Buckwheat No. 3 passes over 3/32 in. mesh and through ⅛ in. mesh.

Birdseye passes over ¼ in. mesh and through $\frac{5}{16}$ in. mesh.

Rice passes through $\frac{3}{16}$ in. mesh (round) and ⅛ in. (square).

Culm passes through 3/32 in. mesh.

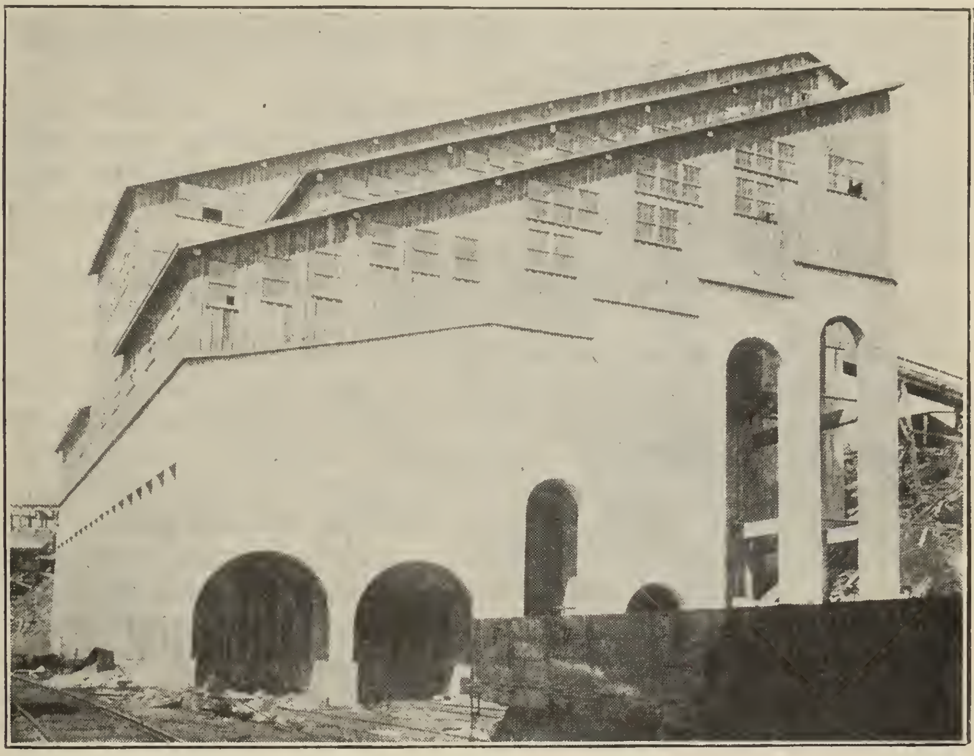
The demand for anthracite varies largely with the season of the year, and during the summer months there is small demand for the domestic sizes. On the other hand, this is the season when coal must be shipped to the territory bordering on the Great Lakes while water navigation is possible. As anthracite does not depreciate by storage, large storage plants have been erected by the transportation companies at tide-water points and at distributing points along the Great Lakes. At the present time probably 5,000,000 tons of anthracite can be stored in such plants.

The labor in the anthracite mines is at present as varied as in all other coal mining districts, and twenty or more nationalities are represented.

Concentration of interest and consolidation of plants have been the policy in the anthracite region for a number of years. Large central plants are rapidly replacing the smaller detached plants, so that one large breaker does the work formerly done by a number of smaller ones. Mammoth central pumping plants or drainage tunnels now drain entire basins, and central power plants have replaced numbers of detached plants. This concentration gives better management, better engineering, and reduced fixed expenses. These economies have been made necessary, as there has been a steady increase in the capital and labor required to produce anthracite. In 1880 coal royalties were from 20c to 25c per ton for prepared sizes, where they are now 50c for prepared sizes, 25c for pea, and 10 to 12½c for smaller sizes. Many of these smaller sizes in former days were thrown on the dump. In 1887 the cost of opening a colliery was $100,000. It is now from $400,000 to $500,000, and often more. Coal near the surface and in many places the thicker

seams have been worked out, necessitating heavier machinery and increased cost.

Anthracite was formerly used in large quantities for making pig iron, but it is no longer in use for this purpose. It is no longer used on steamboats, and production of steam in manufacturing plants with anthracite is confined largely to the use of the smaller sizes. The use of anthracite for locomotives is confined to the anthracite coal carriers, and many of these roads even think it more profitable to use bituminous coal for their freight traffic. Anthracite is par excellence a domestic fuel, on account of its cleanliness and freedom of smoke and the ease with which a fire can be kept.



First Concrete Breaker in the Anthracite Region.

The export of anthracite has been investigated by the railroad companies, but no definite efforts have been put forth to increase the export business.

Discussion.

A. Bement, M. W. S. E.: I have been reminded, since Professor Stoek's subject was announced, of the more advanced engineering methods which prevail in the production of anthracite as compared with bituminous coal. The matter of size is indeed a very important one. Anthracite is prepared in very uniform sizes, and Professor Stoek has referred to the reason. In egg, stove, chestnut, or other sizes, the difference between the largest and the smallest piece of any one of these sizes is very small, so each kind is very nearly uni-

form. As I have said, we have a suggestion for the reason in what Professor Stoek has said,—namely, that it will not burn satisfactorily without it. The reason for this is that anthracite is not easily ignited; it burns slowly, compared with bituminous, and is easily extinguished. The leading reason for its slow kindling characteristic is the small amount of volatile matter, and the slow burning quality is due to a but little understood refractory quality.

In recent years this feature of size has been adopted in connection with bituminous coal. We have now in Illinois, for example, sized coal in the form of the five well-known sizes, Nos. 1 to 5, which those who have to do with coal know all about. The results obtained in burning sized coal are much better than with unsized coal. But I do not think that the value of uniformity in size is realized as it should be.

The production of uniform sizes introduces a complication in the coal business, because the more sizes that have to be made, the more plant is required, with greater fixed charges and maintenance, together with increased labor, all of which increase coal costs.

The increased cost, however, is not the only troublesome feature; a variety of sizes introduces complications in the selling end of the business, because customers must be found for each size made. The simpler way of operating a coal mine would of course be to prepare no coal, but to ship the entire product as mine run. For example, if a purchaser requires egg coal, it is necessary also to produce lump and certain small sizes below the egg. This makes it necessary to find, also, a purchaser for these two sizes, and when a larger range of sizes is involved, the complication is enlarged. As, however, sized and prepared coal is in greatly increasing demand, due to its superior results in combustion, its production is a factor that must be reckoned with, and it would seem that instead of continuing effort to suppress the tendency, it would be better to take complete advantage of it by both producer and consumer.

So I think that eventually we will come to a point, with bituminous coal, which is of such nature that it will retain its form,—a hard, strong coal, such as Illinois and Indiana,—to use prepared sizes for everything where service warrants it, such as locomotives and the harder worked class of steam producing plants,—those cases where it is necessary to get a large capacity. Thus I think we have an illustration in anthracite, of what can be accomplished with bituminous coal, and no doubt we can bring about, with it, the same schemes of storage accompanied by the possibilities of uniformity in production with attendant economies.

In this connection, at the present time some spiral separators are being installed to clean Illinois coal. They have not been put in operation as yet, but are planned, I presume, to take the place of the wet separation and washing, and we shall probably have

a chance, very soon, to see how they work. If successful, they would overcome the disadvantage of wet preparation, which allows the coal to freeze seriously in the winter time,—a present objection to washed coal.

With reference to the use of mining machines in the anthracite region, the coal is hard and very dusty. I dare say that a pick machine could be used. I believe, however, that it would be difficult, on account of the dust, to use a chain machine. Generally the chain machines which have been used have been extremely dusty, and it has been felt by the people who have tried them that they could not be practical on account of this enormous dust production.

It has always seemed to me a pity that cities,—such large, fine cities as Scranton, for example,—should be allowed to grow up above such valuable coal areas. I think it a great economic wrong to have permitted it. There should have been some way to prevent it. The northern basin, for example, is so narrow that one may stand on one side and look right across to the other side, only about six miles. Yet this is next to the widest basin, above which are planted several large cities,—Scranton and Wilkes-Barre being the most important. The cities would have been better situated outside the area of the basins, as we know now by the fact that they are paying a serious penalty for their unfortunate location, especially Scranton, in addition to the extravagant burden their location has placed upon mining.

The anthracite field is very interesting, and if any of you gentlemen desire to visit it, I suggest that you go by way of the Lehigh Valley Railroad as far as Mauch Chunk, ride on the switchback railroad, and visit some of the mines. I can assure you the trip will be well worth taking.

H. P. Fisher, JUN. W. S. E.: I would like to ask if the value of the coal found in the culm banks is reduced in any way by the exposure.

Professor Stoek: That is a disputed point. Several years ago there was a decided dispute between a certain railroad and the mining department of the same road that was furnishing the railroad with washed coal from a culm bank, the mining company claiming that it was just as good as freshly mined coal, while the railroad people did not think so. Many users of washed anthracite will assure you that they can tell a difference and claim that washed bank coal tends to deaden the fire. I know personally of a number of tests that were made to prove or disprove the contention, and the analyses and calorimeter tests did not show any appreciable depreciation. On the other hand, I have been told of analyses that indicated a depreciation.

Mr. Bement: It is my opinion that anthracite coal is not affected by exposure; that it is just as good as when mined, and that this washery product is equal to new coal. I do not think there is any difference at all. As Professor Stoek says, the analysis

does not show it. But there are a number of cases where men know that it is recovered coal; it is in those cases which they know beforehand that recovered coal is involved, that they observe the difference. When they do not know whether new or recovered coal is involved, they do not discover a difference.

I will say, further, that as we go down the scale in quality of coal, we find a very different condition. When we arrive at lignite we find it changes very fast. I think the best bituminous coal will lose probably a quarter to one-half of one per cent per annum. Thus, loss of anthracite from thirty years' exposure I would put at zero. Best bituminous, one-quarter to one-half per cent for the first years' exposure; the poorer bituminous, from two to four per cent; sub-bituminous and lignite, much greater. The principal loss, however, occurs during the first year.

President Armstrong: I would like to ask how close an estimate has been made of the percentage of the available supply of anthracite in the mines at the present day.

Professor Stoek: I can answer that better by saying that the estimate puts the life of the anthracite field as probably 150 to 200 years, judging from the increase in production that has taken place within the last few years. This figure applies to the region as a whole. The Lackawanna region above Scranton to Carbondale will probably be exhausted in not over twenty-five to fifty years; but in the very deep measures of the southern region, there is a long life ahead.

President Armstrong: Is that so much from the beginning of the mining process or from the present?

Professor Stoek: From the present time.

Mr. Bement: There is probably a question as to what can be recovered from the southern anthracite basin; it is so very deep and the measures are so contorted and misshapen that there is quite a question about what can be done with the lower part of the basin. As to its depth, I do not know of any definite opinion. I think the Second Geological Survey put it as 3,000 ft. It may be a good deal more. I would ask Professor Stoek if he has any figures.

Professor Stoek: The old Pottsville shaft was 1,600 ft. deep and was considered a very deep shaft, but there are now a number of shafts 1,800 to 2,000 ft.

Mr. Bement: In the northern or Wyoming field they have gone deeper, because the southern basin is not so fully exploited, and any theory as to depth of the lower portion of the measures is mere geological speculation; and it may be that these measures are deeper than we have any idea of. Depth cuts a very important figure; the quantity of water that will have to be handled will be serious and very expensive. When at the bottom, as the coal is removed a very large problem will be presented in supporting the great wedge of strata above. It will be a complicated

problem at best, and some people have felt that it would be necessary to leave the coal in the bottom, because it could not be gotten out. It is a fact, however, that the steeply-inclined seams afford an opportunity for filling worked-out areas by flushing, and this method may be a very important factor in the life of the basin.

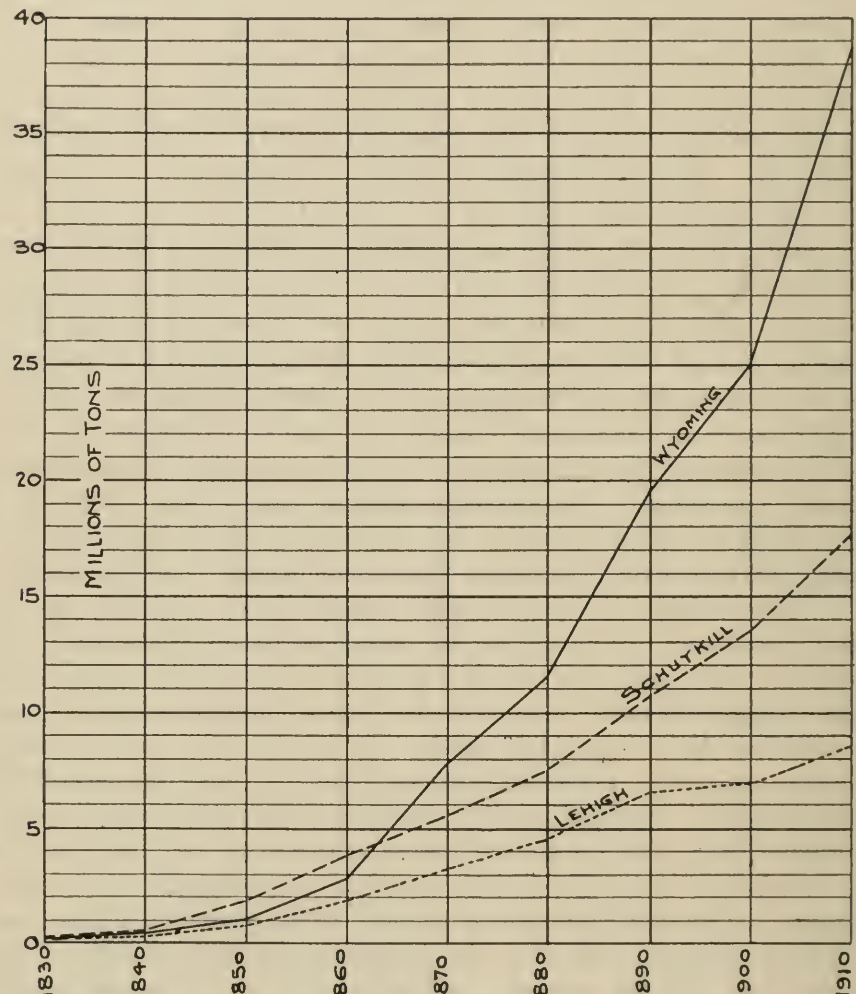
I would add a remark about the quality or kind of anthracite. Hard and soft anthracite are recognized. The hard anthracite is considered to be most desirable for domestic use, because it burns slowly, and for this reason is more convenient and more economical. Those, however, who use anthracite to make steam under boilers usually want it to burn rapidly and make a large fire. Thus, in New York City and Philadelphia, where fine sizes of anthracite are used extensively for steam-making, and formerly used more generally than now, soft anthracite is preferred. The southern end of the southern basin has produced much soft anthracite, possessing a reputation for steam-making as against hard Lehigh, which is considered more favorable for domestic use.

The commercial history of the three anthracite trade regions is quite interesting. Statistical records date from 1820, in which year Lehigh is credited with 365 tons, the other two fields not appearng at this time. Schuylkill first appeared in 1822 with 1,480 tons. Wyoming did not appear until 1829, when it is credited with 7,000 tons. In 1830 the relation was, Schuylkill, 89,984; Lehigh, 41,750 and Wyoming, 43,000 tons. The relative growth of the regions after this time is shown below, from which it appears that Wyoming has had a much more rapid growth than the other regions, notwithstanding that it was so far behind in the beginning. Market and transportation conditions are often the controlling factors in the development of a coal field, but in these respects each field has enjoyed practically the same advantages. The quality of the coal is also practically the same.

The foregoing offers no explanation for the divergent growth. The natural characteristics, and their influence on mining conditions, do afford an explanation. The formations of the northern basin, which constitute the Wyoming trade regions, lie quite level and flat as compared with the territory of the Schuylkill and Lehigh regions; consequently the mining in that basin is much simpler and less expensive. This is also true of the preparation, because there is an opportunity to pick the broken rock out of the coal while it is in the mine, before it is hoisted. In the Schuylkill and Lehigh territories, however, the pitch of the seams is quite steep, so much so that the broken coal and rock will not lay naturally on the foot wall,—or in other words, the floor of the room,—but slides down together in one mass until arrested by such controlling devices as may be employed for that purpose. Thus all preparation must be performed after the coal has been hoisted. The cost and difficulty of mining these steeply-pitched

seams is also greater. In addition, the drainage problem, on account of greater exposure of crop lines, is more serious than with the flatter seams.

In these facts we have a reason for the great development of



PRODUCTION OF ANTHRACITE FROM 1830 TO 1910 IN THE THREE TRADE FIELDS.

Wyoming in comparison with Schuylkill and Lehigh. The difference in output between Lehigh and Schuylkill is due to the difference in the extent of the territory, Lehigh being much smaller than Schuylkill.

THE HARD PAN TEST AT THE NEW COOK COUNTY HOSPITAL

Frank A. Randall, assoc. w. s. e.

Presented Before the Bridge and Structural Section April 8, 1912.

The method used in the hard pan test at the New Cook County Hospital was a comparatively simple one, and could no doubt be improved upon, should it be repeated. It is the first recorded hard pan test made in Chicago, so far as the author has been able to ascertain, and he has been unable to find a record of such a test elsewhere. Hence a description of it may be of some interest and worth while.

The New Cook County Hospital will be a modern fireproof steel supported structure located on the south side of Harrison Street, between Wood and Lincoln Streets. The Caisson Plan, Fig. 1, shows the general layout of the building. The main portion of the structure, facing on Harrison Street, is designated as the Administration Building and East and West Wings. This part of the building is 550 ft. long, about 70 ft. deep, and eight stories high, with a basement below the central portion only, or Administration Building. Four pavilions, with an average width of about 40 ft., and 200 ft. in length, project to the rear from the East and West Wings. The ground area covered is about 75,000 sq. ft.

Preliminary borings for the foundations were made in the spring and summer of 1911 (April, May and July), by S. B. Geiger. Borings were 6 in. in diameter for about 30 ft., and 3 in. in diameter for the remainder of the depth.

These borings, below yellow clay, show a thick stratum of "soft sticky clay" down to about 37 ft. below ground level; with "solid blue clay" running into "hard clay and gravel" down to hard pan at an average of about 47 ft below ground level at the south end and 56 ft. below ground level under the main building. Figure 2 is a record of the borings in detail.

Borings Nos. 6 and 7 show rock at 67 ft. and 89.5 ft. below the surface of the ground, respectively, but the latter figure was considered the more reliable.

Because of the great difference in cost between caissons to hard pan and to rock, and the size of the loads to be carried, it was decided to use hard-pan caissons, provided the test caissons showed a satisfactory layer of hard-pan, with rock in the same relative location as in the preliminary borings.

Bids were received for both pile and caisson foundations. The latter were cheaper by some $13,000, and were used.

Figure 1 shows the number and location of caissons. Caissons Nos. 91, 141, 231, and 256 were chosen as test caissons. Also

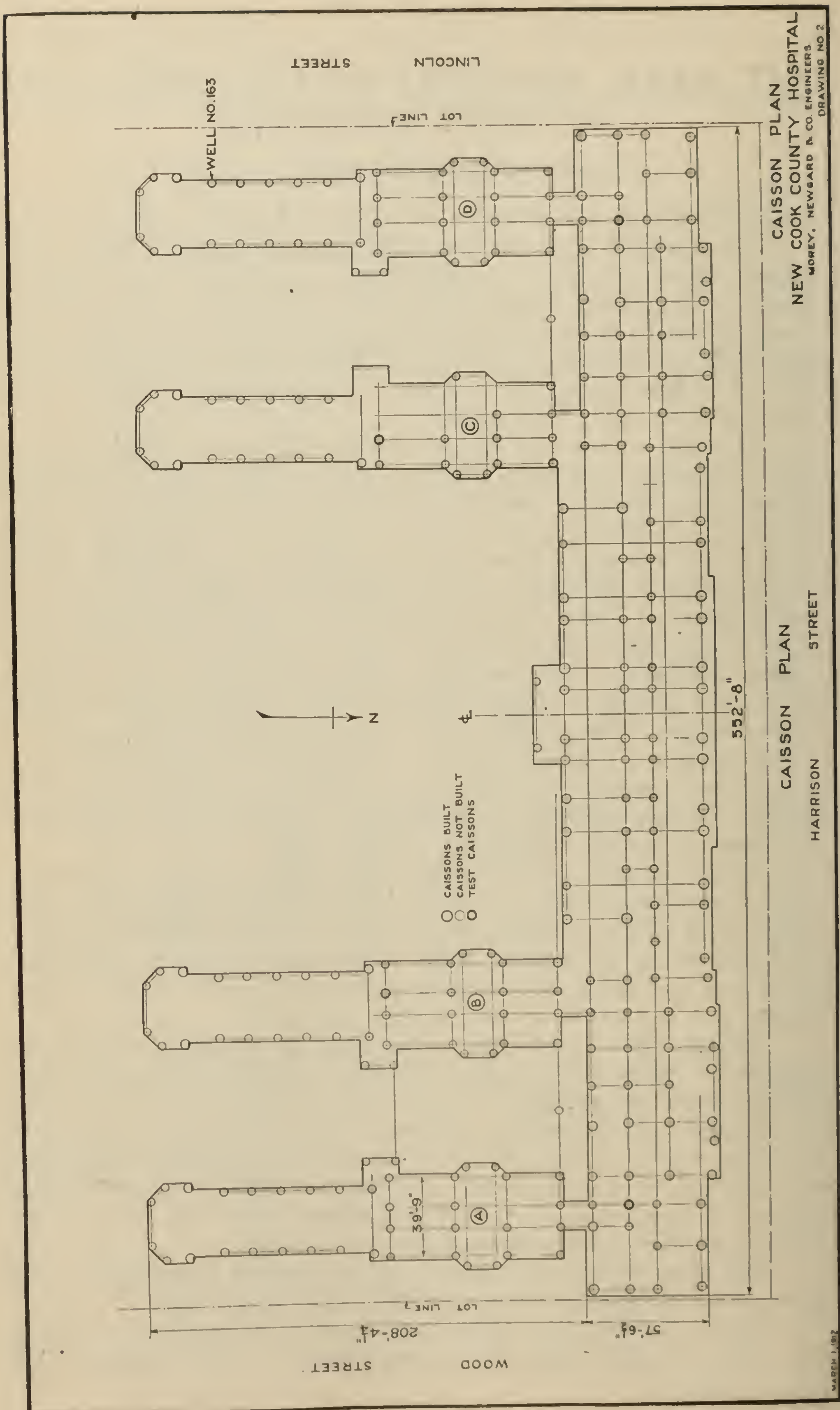


Fig 1. Caisson Plan.

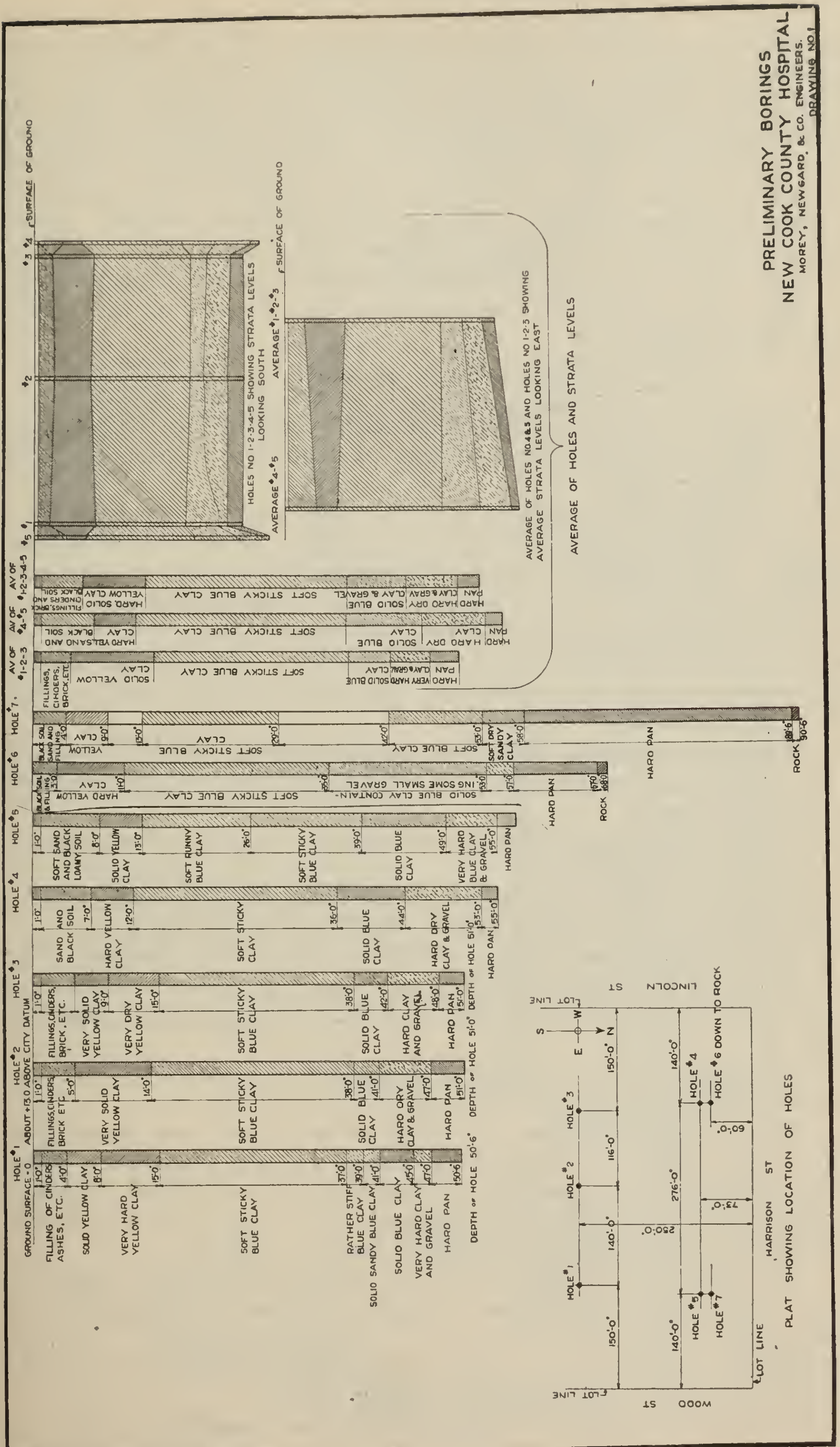


Fig. 2. Record of Borings.

from Fig. 1 it will be seen that these are well distributed as to location. The test caissons were continued on down through the hard pan to 85 ft.; and from soundings and borings, rock was found at 90 ft. below ground level. In order that all caissons should rest on similar material, the wells themselves were not carried to rock. The test caissons were belled at 85 ft. and 60 ft. below ground surface, the top of hard-pan stratum. From the test caissons the thickness of hard-pan stratum was found to be from 15 ft. to 20 ft. with hard clay and gravel beneath.

The test of hard pan was made at the request of the Building Department.

DESCRIPTION OF TEST.

Date, Jan. 26 to 29, 1912. Location, Caisson No. 163,—diameter, 4 ft. 3 in., 64.7 ft. below surface of ground or — 51.17 ft., Chicago City Datum.

Apparatus: The apparatus (shown in Fig. 3) consisted of a loading platform, extra bearing plate, wedges, 12 ft. rod, steel tape, straight edge, carpenter's level, platform scale, 13 tons of pig iron, and tripod with drum for raising and lowering the pig iron.

The timber loading platform consisted of a central post 12 in. by 12 in., with two 8-in. by 8-in. timbers crosswise at the top and covered with 3-in. planking. The post was shod with a steel plate, 12 in. by 12 in. by 1½ in.

The extra bearing plate was a steel plate 12 in. by 12 in. by 2 in., and was used beneath the loading platform resting directly on the hard pan.

Four wedges were used as shown in the sketch, loosely placed, to steady the platform.

The steel rod, 2 in. in diameter and about 12 ft. long, sat in a babbitted hole, 14 in. deep, in the center of the platform.

To the upper end of this rod the steel tape was attached. The rod projected up through the pig iron and thus permitted the tape to be unfastened while the pig iron was being lowered into the well.

The tape was an ordinary steel tape graduated to feet and inches.

The straight edge was as shown in detail, and was found perfect when tested by reversal by means of the carpenter's level, which latter was of more than ordinary sensitiveness and accuracy.

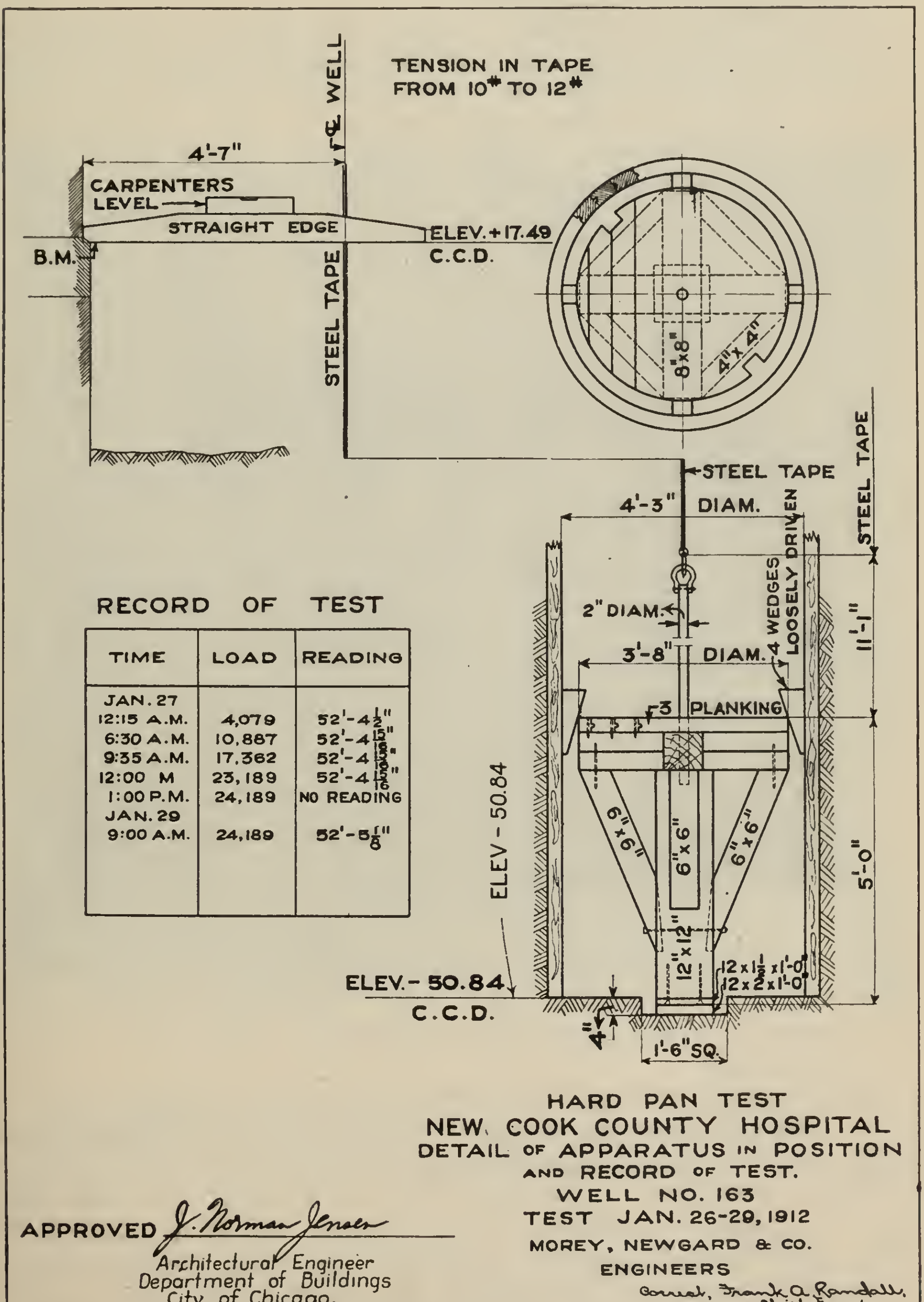
The platform scale was obtained from the hospital and was found correct by checking it against known weights.

Thirteen tons of pig iron were on hand, but only about 12 tons were used, this amount being considered sufficient by all concerned.

The tripod was of ordinary construction such as was used on the work for excavating and filling wells.

Order of Procedure: Water had been standing in the well

for several days and was removed Friday morning. It was necessary to deepen the well between 2 and 3 ft., in order to remove the earth which had been softened by the standing water. As soon as this was done, a hole 4 in. deep and about 18 in. square was dug in the center of the bottom of the well, and the bottom



RECORD OF TEST

TIME	LOAD	READING
JAN. 27		
12:15 A.M.	4,079	52'-4½"
6:30 A.M.	10,887	52'-4 15/16"
9:35 A.M.	17,362	52'-4 13/16"
12:00 M	23,189	52'-4 15/16"
1:00 P.M.	24,189	NO READING
JAN. 29		
9:00 A.M.	24,189	52'-5⅛"

Fig 3. Apparatus.

was carefully cleaned and leveled. The extra bearing plate was then set, leveled, and centered in this hole. It had been intended to enclose the central hole in a wooden box of four sides, to be backed up with concrete and clay to keep all water out of the hole, but water sprinkled in from above directly into the hole, so this method had to be abandoned.

At 5:30 P. M. (Friday) a start was made at lowering the platform, but due to the fact that the platform had to be rotated so that notches would clear the lugs in the rings of the lagging, the platform was not in place until 7:25 P. M. The platform was

Fig 4. Loading Platform.

raised and dropped several times onto the bearing plate in order to force out as much as possible of the earth which had sloughed off into the hole.

The loading of pig iron onto the platform was begun at 8:40 P. M. The pig iron was weighed out in batches, averaging about 600 lb., over the small platform scale, and was lowered and placed as fast as weighed. The pigs were of varying size and were placed in layers of stretchers and headers radiating toward the center, and bonded together in addition by small pieces of wood, as deemed necessary. No pig iron was placed closer than 1½ in. of the lagging, the pile when completed being about 4 ft. in diameter and a little over 12 ft. high.

Five readings were taken, at intervals, the method being as follows:

A permanent bench mark was established upon the water table of the present hospital building within 4 ft. 7 in. of the center of the well. Elevation of B.M. =+17.49 C.C.D. Leveled across from B.M. to tape by means of straight edge and read tape to nearest 1/16 in.

The first reading was taken at 12:15 A. M., Saturday, January 27. Load equals 4,079 lb. Reading equals 52 ft. 4½ in.

Fig. 5. Method of Taking Readings.

The second reading was taken at 6:30 A. M., Saturday, January 27. Load equals 10,887 lb. Reading equals 52 ft. 4 15/16 in., showing settlement of 7/16 in. during the addition of the last 6,800 lb.

The third reading was taken at 9:35 A. M., Saturday, January 27. Load equals 17,362 lb. Reading equals 52 ft. 4 15/16 in., showing no settlement during addition of last 6,500 lb.

The fourth reading was taken at 12:00 M., Saturday, January

27. Load equals 23,189 lb. Reading equals 52 ft. 4 15/16 in., showing no settlement during addition of 12,300 lb.

The loading was completed at 1:00 P. M., 1,000 lb. having been added after the fourth reading, but no further reading was taken until Monday.

The fifth reading was taken at 9:00 A. M., Monday, January 29. Load equals 24,200 lb. Reading equals 52 ft. 5 ⅛ in., showing a settlement of 3/16 in.

The photograph (Fig. 4), taken January 30, 1912, shows the loading platform after being removed from the well, loose bearing plate in the foreground and 2 in. rod on the left.

Fig. 5 illustrates the method of taking the readings.

As has been mentioned, the well tested was a very wet one, due to the fact that two sewers (6 in. and 9 in. respectively) were cut into in sinking the same. This well was the wettest one encountered. About 12 ft. to 14 ft. of water stood in the well during the test.

When the platform and bearing plate were removed, it was noted that ⅛ in. of compressed earth adhered to the top of the loose bearing plate.

CONCLUSIONS.

The caissons were designed for 44,000 lb. per sq. ft. at the top of the caisson, and were belled twice the diameter of the shaft. Considering hard pan at 60 ft. below the surface, the unit designing load on the latter is about 13,300 lb. per sq. ft., or about one-half of the test load. The test load was applied to 1 sq. ft., while the area of the well was about 16 sq. ft. It is not known how much the bearing value of the hard pan is increased when the caisson is completed and the well is completely filled. but it must be a very material increase. The results indicate that the hard-pan stratum will carry the load designed for with safety. Doubtless a portion of the settlement was due to the compression of the loose soil which sloughed off as the platform was being lowered. It is interesting to note that the well stood open ten days after the excavation was completed. No settlement was detected in the footings alongside of the wells.

The results of the test were satisfactory to the Building Department.

The test was conducted by Messrs. Morey, Newgard & Co., under the personal supervision of the author. Mr. J. Norman Jensen, Architectural Engineer, represented the Department of Buildings, City of Chicago, and was present at all times during the test. The W. J. Newman Co., contractors for the caissons, supplied the labor and material.

DISCUSSION.

Wm. Artingstall, M. W. S. E. (Chairman): I think there is no subject which the Bridge and Structural Section could bring up

which would be as important as the one we have under discussion tonight. By referring to any of the old plans (if you happen to be fortunate enough to get hold of them) which show the bearing power of the soil as assumed by the different architects or engineers, in the downtown districts, you will be surprised to see how a certain figure is adhered to. Some architects will take 1½ tons per sq. ft., some 2 tons, while others compromise on 1¾ tons. I have in my office a plan, compiled some six or seven years ago, which shows all the buildings in the downtown district, for which I could find the bearing value of the soil, as assumed by the different architects or engineers in designing the different foundations. For some of them, one architect has taken 1½ tons, while his neighbor on the next 25 ft. has run up to 2½ tons on practically the same character of soil. (I say the same soil because all the footings are at about the same elevation, i. e., datum.) But when you get down a little below datum, or minus five, it is a question whether the soil is the same on some one 25 ft. lot as it is on some other lot. You will find that every man that is making borings in the city of Chicago will say a soft blue clay, because he is making wash borings and does not know whether he has a soft clay, medium clay, sticky clay, or anything else. I have gone through 6,000 to 8,000 lin. ft., taking out everything for a width of nearly 40 ft. and a height of from 30 to 50 ft., and although in daily contact with the work, I could never tell, from the dump, whether the excavation was made at 10 or 40 ft. below datum. At one place we would strike a real soft spot, and possibly 20 ft. away we would be working in a fairly hard material.

An amusing thing to me is that in taking wash borings you will find that probably nine out of ten of the engineers making the test will say they have found quicksand. I solved that, to my own satisfaction at least, in one piece of work, where we opened up a stretch and found a very fine dry sand, which lay in the form of a lens about 30 ft. in length and breadth, and possibly 30 in. thick. While the sand was as dry as a bone, and so fine that we could hardly feel it (it was finer than flour, but would run just like shot), the moment it came in contact with water we had quicksand. I think that is what most men encounter in making borings in different places, and what they record as quicksand at about minus 50 or minus 60.

T. L. Condron, M. W. S. E.: What do you term that material when you find it?

Mr. Artingstall: I do not believe it has been christened yet. It is apparently sand, but it is so fine that one cannot call it sand.

Mr. Condron: Is it quite different from silt?

Mr. Artingstall: Yes, it is sharp. That is, if you could get it towards the outer sides of this lens you would find it coarser than it is in the middle. It seems to be a white sand; more like silica than anything else.

In regard to the author's remarks about the probability of the hard-pan test made at the New Cook County Hospital being the first one made in Chicago, I think there was one which preceded that. About six or seven years ago we were underpinning the Van Buren Street railway tunnel, and encountered quite a number of difficulties. This tunnel was built with the aid of a cofferdam, and we found that a considerable number of piles projected inside the line of the wall. We had figured the new footing at about 4½ tons, and a width of from 5 to 7 ft. per lineal foot as our bearing area. It is needless to say that we were much perturbed when we found some of these piles projecting anywhere from 2 ft. to almost the inside face of the wall. So we decided to make some tests on the bearing power of the soil to determine what might be considered the safe load, and then confine ourselves as nearly as possible to the unit so established. We had already built the new steel girder roof, so there was only a distance of about 14 ft. from the bottom flange of the girder to the clay, which was of a fairly hard character, such as could be "grubbed," but still not too hard to dig with a clay knife.

We were particularly concerned with the question whether or not the area of foundation had much, if any, influence on the bearing power of the soil. In other words, if the material was confined, could it sustain a heavier load, and, if so, how much? Consequently it was necessary to make several tests with increasing bearing areas. The first test was made by piling bricks on a platform supported by four legs each ⅞ by 1⅞ in., and noting the load (approximately 7½ tons per sq. ft.) when the settlement was ⅛ in. This slight settlement was taken because it was impracticable to leave the test standing for any length of time. For the next tests we rigged up a device which could be easily handled by two men. This was merely a "drum" with the upper end bearing against the bottom flange of a girder, and the lower end resting on a bearing plate in contact with the clay, which was first made level. A dynamometer was connected directly to the lever arm, and the block and tackle was fastened so as to obtain a direct pull. The reading on the dynamometer then had to be corrected merely for friction in the jackscrew. A new location was taken for each test, but as all tests were within 5 ft. of each other, there could not be much difference in the character of the clay.

The following results were obtained:

Size of Bearing.	*Load.*
4 by 4 in.	8 tons per sq. ft.
6 by 6 in.	12 " " " "
8 by 8 in.	22 " " " "
8 by 12 in.	32 " " " "
12 by 14 in.	49 " " " "

This proved to our satisfaction that we could load our foundations with a much heavier load than we had assumed, and in the

river section of this tunnel the foundations are carrying nearly 10 tons per sq. ft. The maximum settlement, as shown by a set of levels run eleven months after completing the work, was only ⅛ in.

F. E. Davidson, M. W. S. E.: The writer has always considered that the proper distribution of the dead and live loads upon the soil supporting engineering structures was of more importance than the allowable loading on the soil itself. If the foundations of a structure are designed with proper consideration to the distribution of the various loadings, and with strict reference to the character of soil found when the excavation for the foundations has actually been done, then the writer believes that the allowable loading upon the soil per unit of area is of minor consideration, as the structure will settle in any event, but the settlement will be uniform.

It is the writer's practice to provide, in all contracts for foundation work, for unit prices for concrete either added to or deducted from the foundations indicated on the plans upon which contracts are based. It is his practice to make a careful examination of the actual soil encountered after the excavation has been made, and if the soil actually excavated does not agree very closely with what has been shown by test borings or test pits, to re-design the foundations in accordance with what the character of the soil would indicate would be its safe unit load. What the safe unit load would be in any case is a matter of judgment based upon experience, and cannot be determined by any rule or formula.

The writer has loaded hard clay to as much as 7,500 lb. per sq. ft., and the structure placed thereon, after having been completed and used for a period of five years, shows no unusual settlement.

Any foundation constructed on clay will settle. The problem is to so design the building that the settlement will be uniform. As an illustration of what may be expected to be encountered in the construction of a large building, the writer will refer to his experience in connection with the Hecht factory building, which covers the block between Congress and Harrison Streets, on the west side of Throop Street, Chicago. Before the working drawings for this building were started, a number of test borings were made to a depth of 50 ft., and in addition thereto a test pit was dug to a depth of 28 ft. The writer's judgment at that time, based upon the character of soil encountered in sinking the test holes and test pit, was that the soil would with safety withstand a load of about 4,500 lb. per sq. ft., and the foundations were designed upon this assumption. But after work was started, an old ravine was encountered, extending diagonally across the building area in a southeast and northwest direction, almost directly under one of the main fire walls of the building, and also underneath the supports for the gravity tanks, etc. The upper layers of this soil were of such a consistency that, in the writer's judgment, it would not carry with safety a load to exceed 1,000 lb. per sq. ft. until a depth of about 20 ft. was reached. When the character of the

clay changed from a very soft clay to a clay of much firmer consistency, and one which the writer believed would carry with safety a load of 3,000 lb. per sq. ft., the foundations for the building were re-designed; a unit of only 3,000 lb. was used wherever the soft clay was encountered, and the bottom of the footings was extended to a level of from 14 to 20 ft. below the sidewalk grade, although the footings for the building, where good clay was found, were only extended to about 6 ft. below the sidewalk grade. This will illustrate the danger which the engineer and architect encounters in designing foundations for any important structure, unless provision is made for the re-designing of foundations after the actual excavation has started.

A careful check for the settlement of this building was made after the building had been completed, occupying four months, and the settlement was found to be almost uniformly 3/8 in., except in the case of two column footings, which had settled approximately 5/8 in.

Where lake sand is encountered, the writer would not hesitate to load a foundation to as much as 7,500 lb. per sq. ft. if the stratum of lake sand is 20 ft. in thickness, but under no consideration whatever would he ever load a sand sub-soil with a unit of more than 3,500 lb. per sq. ft., unless the bottom of the footing was below any possible excavation in any adjacent property.

The unit stresses permitted by the Chicago Building Code are very conservative and safe for light structures. The writer believes, however, that the engineer having important factory work will use his own judgment as to the proper unit stresses to use, and not depend on the Chicago Building Code or any text-book. He also believes that the Building Department of Chicago will not restrict the loading of soil to the unit stresses mentioned in the Code, where the reputation of the engineer designing the structure is sufficient guarantee that the structure will be safely designed.

In order to provide for uniform settlement in structures subject to both live and dead loads, the proper distribution of the assumed live loads is as vital and important as the selection of the proper unit stresses. Parts of structures subject to great dead-load stresses will settle more than foundations whose load is largely live load, unless great care is exercised in determining what unit stresses to use in the various cases of loading which occur. There are at least three kinds of loading in building construction which must be considered in the design of foundaton work: First, the dead weight of the structure. Second, the area upon which there may be live loads. Third, impact loading, such as the vibration of heavy machines, or the effect of impact from a large number of elevators. Probably the most difficult problem in connection with building design is to so proportion these loads that the settlement of the structure will be uniform.

It might be well to mention a few well-known instances of unequal settlement, as illustrating the extreme difficulty of so proportioning the unit stresses on the foundations as to provide for the uniform settlement which all engineers and architects hope to secure. First may be mentioned the Unity Building, which is now about 27 in. out of plumb. Second, the Masonic Temple, which has settled toward the east very materially. Third, the Board of Trade Building, where the settlement under the tower was of such a serious nature that a few years ago it was necessary to demolish the tower in order to save the structure.

J. W. Pearl: I have heard no mention, this evening, of Rankine's formula for earth pressures. This formula has been before, and in use by, the engineering profession for nearly sixty years, and up to the present time I know of no instance in which it has been controverted. A great many engineers, in using Rankine's theory for earth pressures, start with the presumption that it is an absolute formula for the design of work they have in hand. If they would read Rankine's discussion of it, which appeared about 1857, they would find that the formula is based on the assumption of materials devoid of *adhesion* and *cohesion*. Any engineers who use, or authors who quote, this or any other formula (and they are legion) without a thorough knowledge of its derivation and limitations, have no right to condemn it or use it as an apology for defective work that may be explained by such limitations as stated by Rankine on page 212 of his *Applied Mechanics*, and page 324 of his *Civil Engineering*.

As I believe everyone who has had to do with foundations in an engineering way knows, the deeper the foundation is placed, the more it will support safely, or the more nearly uniform will be the settlement. One of the previous speakers stated in his discussion that he "would not hesitate to load a foundation to as much as 7,500 lb. per sq. ft. if the stratum of lake sand were 20 ft. in thickness."

I believe the load that may be carried on any given soil is absolutely proportionate to the depth of the foundation, or rather the pressure on the surrounding soil. There is no particular risk in loading material, such as clay or sand, with 3,000 lb. per sq. ft. under proper conditions. One can take a piece of 12 by 12 timber 48 ft. long, place it vertically in water, and, including its own weight, it will carry 3,000 lb. per sq. ft. Anyone who chooses to figure it will find this to be true. I believe there is a definite relation between the depth of foundation in the soil and the amount it will support safely or wth equal settlement. In my opinion, in any determination of the supporting power of a foundation, the depth of footing and the load applied upon the contiguous earth, should be entered as a function in the solution of the problem. The practice in Chicago does not seem to take this into consideration, and I do not understand why it does not.

O. H. Basquin, M. W. S. E.: The first experiments that were described this evening seem to me to give a result that is probably not as large as the soil is capable of bearing, because that load is applied over an area in the center of an excavated area. The hole was deep, but the free surface in all the excavated area was only 4 in. above the loaded area, so that if this load were a great many thousand pounds on a 4 in. depth, it would doubtless carry a great deal more, if the overlying earth were 50 or 100 ft. deep.

A few years ago, Mr. E. P. Goodrich gave a paper before the American Society of Civil Engineers, on lateral earth pressures, and in that paper he described a piece of apparatus whereby one can determine the coefficient of friction of a sample of earth. I became interested in this problem, and had a piece of apparatus made up, which was tried once in the laboratory. It did not work very well the first time we tried it, but I think in a short time it will be in good workng order. If I could have samples of soil similar to that of the tests described this evening, I should be glad to see what could be found out about the coefficient of friction and the cohesion of that material. It seems to me it might be interesting to have such results added to the papers already given.

Mr. Randall: The caissons have not all been sunk. I shall be glad to supply Professor Basquin with samples from the next caissons sunk. Our test was at the bottom of a 60 ft. caisson. The bearing plate was placed in a hole 4 in. deep and 18. in. square, in the center of the caisson.

A Member: I would ask Mr. Randall what the assumed load was that was put on the caisson or piers?

Mr. Randall: The designing load was 44,000 lb. at the top of the caisson. This amounts to about 13,000 lb. per sq. ft. on the bottom of the caisson.

C. K. Mohler, M. W. S. E.: Figuring the weight of earth at 100 lb. per cu. ft. gives a vertical load of 6,000 lb. per sq. ft., at a depth of 60 ft. Plastic clay should balance that amount of column load without any settlement whatever.

If the foundation well is completely filled, there will be the friction of the sides of the column against the earth to resist settlement. With the clay perfectly confined at a depth of 60 ft. there should be no settlement possible, aside from what the soil may be actually compressed by the added load. On the other hand, a compression test in an open pit on plastic clay may be no criterion whatever of what it will carry when perfectly confined. To illustrate, suppose the clay is firm enough to be just on the point of flowing or heaving from the pressure when it is uncovered at a depth of 60 ft. Then if it is reloaded with 6,000 lb. per sq. ft., perfect equilibrium should be restored, and no settlement take place. If you consider a tight-fitting column or piston neglecting friction on its sides, the soil directly below the piston should sustain a load of 12,000 lb. per sq. ft. before there is any tendency to flow or heave

beyond the edges of the piston. The only possible settlement would be the compression of the soil below the base of the column or piston, whatever that might be.

Suppose the soil is an incompressible but plastic clay that would begin to flow or heave under a load of 3,000 lb. per sq. ft. in an open pit test. Under an increase in load, settlement will take place on account of the flow and heaving around the loaded area. If, on the other hand, the piston is perfectly confined, no settlement can take place from heaving until the entire depth of the soil surrounding the column has been lifted. The balancing weight would not be a simple vertical cylinder surrounding the pier, but would be a cone with the surface radiating out from the base of the column, and making an angle with the vertical equal to the angle of friction of the material.

Sand does not readily transmit pressure, and will take a very heavy load before it gives much lateral pressure. But clay, after being loaded enough to overcome the cohesion and friction (depending on the fineness of the clay and the amount of contained water) will very readily transmit pressure; and in the case mentioned, 13,000 lb., if it were not for the friction of the clay on each side to keep it from moving, we would not get a safe foundation if it were the putty clay. On confined sand at that depth, one could impose an almost unlimited load without heaving and with very little settlement. Mr. Davidson is unquestionably right in thinking that sand will carry a much heavier load than clay. This may be noticed to a very marked degree in Chicago, when excavating for new buildings. I have in mind the case of the Karpen Building. Evidently not enough care was taken when excavating for the basement, and the material flowed in from the sides and possibly the bottom of the pit, resulting in a crack near the center of Michigan Avenue, to the east, and also to the north and south of the building. I believe this putty clay will readily come up from the bottom unless the sheath piling is driven well below the bottom of the excavation. We probably get into a good deal of trouble in not properly safeguarding against heaving from the bottom.

I may mention, also, the excavation for the McCormick Building Annex. The excavation had not gone down to any great depth, and the sides were apparently well braced, but the material ran in, resulting in a building across the alley being badly damaged by settlement. A vertical crack opened from top to bottom, of a width of about 1 in. at the top. The Cowan Building to the north settled and cracked. The disturbance extended clear through that building, and affected a section of the Stratford Hotel site of about 100 ft. The Cowan Building had a party wall, and an endeavor was made to take good care of it. I think the trouble in that case was simply that the load on the foundation squeezed the clay up vertically as well as laterally.

We have a good example of how soil will flow laterally and heave in the case of building railroad banks over swampy and peaty soil. There the surface may be apparently solid for some depth. But when a bank 10 or 15 ft. high is placed on thin strata underlaid with some depth of peat, it often happens that the imposed load will cause the peat soil to flow out from under the fill and heave the soil on each side until the fill "strikes bottom" or the toes of the slopes heave enough to balance. I have a case in mind where the bank was about 12 or 13 ft. high, and it broke through the crust and settled, lifting the swampy surface about 40 to 50 ft. out from the toe of the fill, and threw over trees a foot or more in diameter.

The above illustration has an important bearing on "bearing power tests" in the following way: Suppose a layer of very hard and incompressible material is underlaid with a layer of unstable or flowing material. An intensive test on a small scale for bearing alone on the hard material would give no indication of the load that the upper layer would bear before it would break through, on account of flow of the under strata.

We should not place too much confidence on the indication of a soil test to carry a load, or assume that a poor showing for bearing power, on the other hand, may not be perfectly satisfactory under favorable conditions. We have to use common sense and good judgment with the conditions met in each problem.

Mr. Artingstall: I do not think there is any question in the engineer's mind, about the moving of the soil. Of course, on opening up any large excavation, one will have a great deal of trouble about the bottom coming up. It is one of the greatest banes of the contractor's life. The late General Fitz Simons, a very bright engineer in Chicago in the early days, and afterwards President of the Fitz Simons & Connell Dredge & Dock Co., always contended that the bed of the Chicago River was being continually raised by the enormous pressures of the buildings in the downtown district squeezing the soil and bringing it up in the only place it could find relief,—that is, in the river bed. It is a notable fact that since 1856, or 1857, dredging of virgin clay out of the Chicago River has been going on, and about every five years one can take out two or three feet and get down to the desired plane at the bottom, whatever you want to dredge to say minus 26 or minus 27 ft., but four or five years afterwards you can again take out two or three feet of solid clay, every bit of which is above the former limit of dredging.

J. T. Walbridge, ASSOC. W. S. E.: I do not know that I have anything to add that would be of interest to the members of the Society, but I might say that prior to the reconstruction of the Washington Street tunnel, I had had occasion to look into the subject of earth pressures in trenches, and found the same conflicting theories as to the point of maximum pressure as has been mentioned

here this evening. In constructing the west approach of the Washington Street tunnel, an open cut was made, which in some places was about 45 ft. deep, and I had hoped to be able to note the condition of pressure here with some degree of accuracy. However, no adequate means for making tests were at hand, and as near as could be observed the point of maximum pressure occurred at varying depths at different sections along the trench.

Regarding the heaving of the bottom of the trenches in clay, this is not at all uncommon, and I have observed the earth to rise to a very marked degree in some cases. I had occasion to observe the earth pressures in a case where single sheath cofferdams were built in about 10 ft. of water, and the coffer was excavated to a depth of about 25 ft. before any of the water was pumped out. The material surrounding the dam to this depth was mostly a fine silt. Before pumping, very heavy pressures developed below the river bed, which was somewhat contrary to theory, and could probably be accounted for by the fact that considerable blasting had been done near the coffer. It would be interesting to know just what condition of pressure prevailed before pumping, in a case like the one just mentioned.

Mr. Artingstall: I believe Dr. Waddell made some studies of earth pressure with respect to a building for which he expected to get the contract in the City of Mexico. That soil, as you know, is practically a fluid earth, so most of the buildings are only about a story, or a story and a half high. Dr. Waddell recommended that they confine the earth; that is, build a mat over the whole site of this public building, and extend the sides down, so that what he would really have had when he got through would have been an inverted box. As he stated in the *Proceedings of the American Society of Civil Engineers* a short time ago,—a couple of years, I believe,—the only reason that he did not have an example of that experiment is that he failed to get the contract.

Mr. Pearl: There is one instance of flow of soil which perhaps is not familiar to all of those present. At the time of the excavation of the caissons for the County Building, the old City Hall moved laterally 2⅝ in. at one corner, I think,—as well as settled. I do not remember what the movement was at the other corner. Prior to the construction of caissons for the County Building, the engineers placed heavy iron rods through the foundations of the old City Hall, to tie them together to guard against spreading or unequal settlement. The rods prevented spreading, but during the construction of the County Building the entire City Hall moved laterally about as stated.

Mr. Artingstall: In regard to Section 1 of the Washington Street tunnel, which extended from Clinton to Canal Street, work on the Northwestern depot had just begun at that time, so there were no buildings in that block—Clinton to Canal Streets—nor between Madison and Lake Streets, and all we had to contend with was

the foundation piers for the C. & N. W. Ry. columns. These were on piles driven down to about minus 50 or 60. They not only settled, but moved in a manner similar to that mentioned by Mr. Pearl. Of course, we did not acknowledge that at the time, but we knew it to be a fact. I think there was nearly 2 in. lateral, and 2½ in. vertical movement.

F. L. Stone, M. W. S. E.: In the track elevation work of the C., B. & Q. R. R., we had occasion to excavate from Canal Street westerly to the city limits. In that stretch I think we found every kind of soil which exists in Chicago. At some points, especially near Morgan Street, we found it very fluid. We were taking test borings while we were driving piles about 80 ft. distant, and the lateral movement of the clay stopped the work of making the borings. The holes were closed, so that when we pulled the augers out we could not get them back. Again, we found that in excavating some of the soil, when brought up from the caissons, would be sharp cut with a spade, apparently solid, but in wheeling up on to a flat car, by the time the wheelbarrow was going up the plank runway, the mass would collapse and run off the sides, just like quicksand. Our greatest trouble in holding our abutments was in connection with the lateral movement. We found we were able to carry our loads vertically on piling, but we had to take considerable precaution as to the lateral movement of the abutments. At Center Avenue the abutments were in before we dug some of the caissons, and while digging these there was considerable movement of the abutments. After the caissons were filled, the abutments stopped moving and there has been no further trouble.

Mr. Condron: One feature of the foundation problem in Chicago that will eventually require legislation, it seems to me, is the practice of sinking big foundations, pumping them out or bailing them out, as the case may be, and removing from the excavation an unlimited quantity of material. This must disturb the surrounding soil, and accounts in a large measure, in my opinion, for the settling and lateral movements of surrounding buildings. In every one of these deep foundations, or nearly every one, more or less water is encountered. It is not unusual for pumps to be put in to pump out sand and water, with the hope of getting a dry place farther down. Sometimes that is successful; often it is not. But it would seem as if, in justice to all interests, there should be legislation which would prohibit that kind of pumping or baling under the ground of a great city like this. And where it is impossible to do dry excavation, the excavating should be either stopped or carried on under compressed air. A good many of our large buildings have hard-pan foundations, and they will carry an indefinite amount of load until somebody pumps out the material, silt or quicksand, beneath the hard pan. It is not common knowledge that there is, underlying the rather substantial hard pan in many parts of this city, a fluid or semi-fluid mass. You may call it quicksand, or

silt, or what you will. As long as it is confined, it is as good for carrying load as any other material; but what the effect will be on even these hard-pan foundations, when the surrounding country is pumped out, cannot be imagined. I was hoping that mention would be made of some experience in that line.

Mr. Artingstall: If we are going to legislate against excavating or pumping of caissons, I think we will also have to legislate against artesian wells. It is a well-known fact, I think, that the artesian wells which have been sunk in and around Chicago in the last fifteen or twenty years have lowered the water plane very materially. The first caissons which were sunk invariably struck water before they struck rock, and now it is almost unheard of to find water above the rock. We find a little, possibly, particularly on a Monday morning. It may seem strange to find it on Monday, but men who are in charge of sinking caissons tell me that more water is found on Monday than on any other day in the week. This is probably due to the fact that there is so little pumping from the artesian wells on Saturday nights and Sundays. At least, I draw that conclusion from remarks made by Mr. Alvord, who has gone into the question of artesian wells around Chicago. At the time that the Commonwealth Edison Co. ran a tunnel along Washington Street, they found about 40 ft. of water in the shaft one morning, and were very much excited, as they thought the water had broken through from the river. But by the time they got their pumps, there was absolutely no water in the shafts or in the tunnel. Mr. Alvord explained, at a past meeting of this Society, that this was probably caused by the pumping from artesian wells.

Mr. Stone: We had one case at Center Avenue, where our experience was quite the opposite. Our caissons were 14 ft. centers, and we had put several down that were perfectly dry, and in one it cost a little over $1,000 to get the best of the water. The other holes remained dry. We decided that the trouble was due to leakage from the old water tunnel that runs near Blue Island Avenue crossing Sixteenth Street in that vicinity.

Mr. Randall: I would like to say, in reference to Mr. Condron's remarks, that we were fortunate enough not to find any water above rock in our test caisson, which ran down about 90 ft., so we have little fear of the water being removed from beneath the hard-pan stratum.

W. L. Cowles, M. W. S. E.: I recall one instance that may illustrate the difference in the variation in pressure in the soil of Chicago. In the construction of the Illinois tunnel, where progress is discontinued, it has been the custom, of course, to seal up the heading with a good solid wall of concrete, and occasionally, when the tunnel has been continued and that wall of concrete has been removed, it has been found, rather to the surprise of the constructors, that the soil had receded from the back face of that

wall, showing that there was a contraction and apparent drying out of the soil. That is only in some cases, of course.

A. Bement, M. W. S. E.: Mr. Condron's remarks have reference to a matter which has, to me, seemed to be of much importance. In a number of cases a considerable volume of water has been removed from foundation wells when the excavation has reached the stratum just above the rock. Those who pass the northwest corner of State and Van Buren Streets may have noticed, recently, a more or less continuous pumping of water which was discharged on Van Buren Street, finding its way into the sewer at the corner. This water came from foundation wells and contained considerable sand,—so much, in fact, that provision for its removal was necessary before the water entered the sewer. There is no doubt in my mind that settlement of strata must ensue from this cause. My attention was first drawn to this matter when the foundation wells of the new C. & N. W. Ry. station were put under air pressure. At that time it was reported that some of this air found exit in other wells across the river, when excavation had reached this stratum. In the discussion of Mr. W. C. Armstrong's paper,* I endeavored to bring up this matter, and referred to it as a serious matter. The author of that paper, however, did not agree with me, and I am much gratified to find that those so qualified as Mr. Condron and the Chairman have presented the matter so clearly.

*Journal, Western Society of Engineers, December, 1911, pp. 1001-4.

THE BEARING POWER OF MOIST BLUE CLAY

RESULT OF TESTS IN THE LOOP DISTRICT, CHICAGO, ILLINOIS.

EDWIN HANCOCK, M. W. S. E.

The following tests were made in March, 1911, in the manner described:

Two openings about 8 ft. square were made in the concrete floor of the basement of the Federal Building, and the soil was excavated for a depth of 6 ft., so that there was a bearing on the original clay which had never been disturbed. On this clay a grillage was built up of planks 2 in. by 12 in., 2 ft. long. These planks were laid closely together so as to give a bearing of 4 sq. ft. This grillage was built up about 1 ft. high, and upon this was placed longer planks, upon which the load of pig iron was placed.

The settlement was taken by means of a wye level and rod. Readings were taken as soon as each load was put on, and then again after giving an hour for settlement. If no further settlement had occurred, a larger load was placed upon the plank. If the settlement had increased, readings were taken until they showed that the settlement had ceased.

The elevation above city datum of the street opposite this test was 14 ft., and the elevation of the clay upon which this test was made was 0.00. The lateral distance between the tests was 150 ft.

Following is a list of the loads and settlement:

TEST No. 1.

Load per sq. ft. in lb.	Settlement.
1000	3/16 in.
2000	1/2 in.
3000	1 3/16 in.
4000	1 3/4 in.
One-half hour later, 4:30 p. m., same load	1 7/8 in.
Next day; same load	1 7/8 in.

TEST No. 2.

500	No settlement.
1000	3/32 in.
2000	7/64 in.
3000	3/16 in.
4000	3/8 in.
One hour later	7/16 in.
Two hours later	29/64 in.
Four weeks later, 4:00 p. m.	5/8 in.
Next day, 9:00 a. m.	15/16 in.
4:30 p. m.	15/16 in.

LATERAL PRESSURE IN CLAY FROM SUPERIMPOSED LOADS

WALTER L. COWLES, M. W. S. E.

Much has been written on the subject of earth pressure in general, and many have been the theories evolved relating to the stability of retaining walls, and the intensity and point of application of the pressure exerted by a mass of earth against the back of such a wall. In certain forms of construction the lateral pressure against a retaining wall or any vertical surface, induced by a vertical load applied at a given distance from that surface, becomes a matter of special interest.

Having occasion to determine the amount of such pressure, I made a careful examination of the literature on this subject, with the result that I discovered a wide divergence of opinion as to the location of the maximum pressure as well as to its amount, varying from a maximum at the bottom of a cut to a maximum near the top, while the arguments advanced from a theoretical point of view, as well as the results of experiments and of observations of actual conditions under varying circumstances, might favor either conclusion.

Moreover, in the experiments described, the materials used were granular in character, the theories advanced were for the most part based on the action of granular substances, and the conclusions were not applicable to masses of clay such as constitute the subsoil of Chicago.

In a few instances (notably in a paper by Wm. Cain, M. Am. Soc. C. E., published in the Transactions Am. Soc. C. E., Vol. LXXII, pp. 403-448) pressures from clay have been discussed, including the effect of cohesion. This was in line with the general direction of the investigation which I was conducting, but still did not touch the particular point with which I was concerned, namely, the horizontal effect of a vertical superimposed load.

I therefore sought to deduce a formula which would at least serve as a basis for the determination of such pressures, and to that end made certain assumptions, as follows:

(a) The effective pressure from a superimposed load, per unit of surface, will decrease as the distance from its point of application increases, and will, at some distance, d, be so dissipated that it will be inappreciable and its amount may be considered equal to zero.

(b) The pressure in a horizontal direction will equal zero.

(c) The load may be considered as being supported at the apex of a cone, whose elements make an angle with the horizontal equal to the angle of internal friction of the material considered.

Clay, being a plastic instead of a granular material, has no "angle of repose," since, in excavating, it may be left with a vertical surface of considerable height; therefore this angle, commonly used in discussions of lateral pressure, is inapplicable to this material. Clay, however, has cohesion, and offers a certain resistance to shear due to its tenacity, and exerts also a resistance, due to its friction,

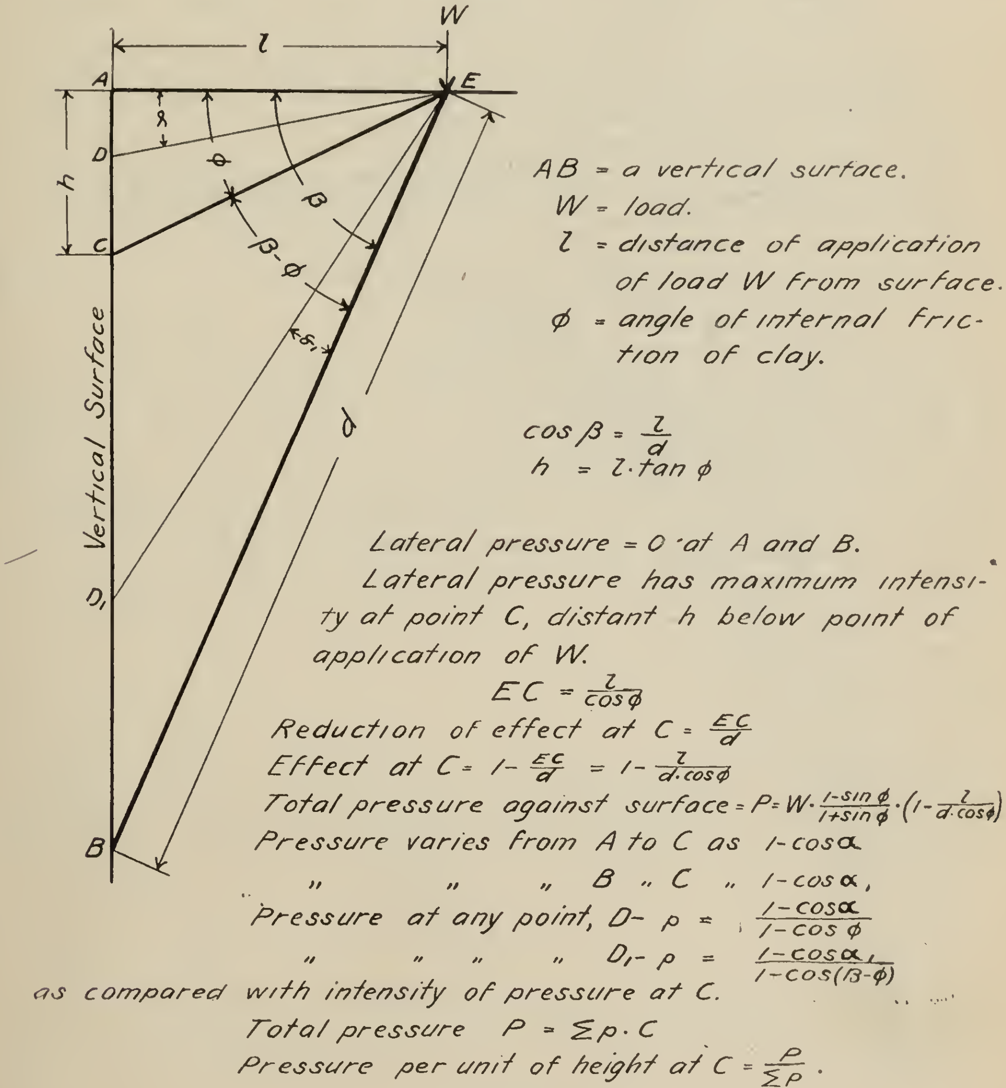


Fig. 1.

against the movement of one portion of a mass over the underlying portion. The coefficient of this friction may be determined, and the angle of internal friction is that angle whose tangent is this coefficient.

Let us, then, consider an open cut with a vertical face, and a vertical load, *W*, applied at a distance, *l*, from the surface. Pass a plane through the point of application, and perpendicular to the face

of the cut, cutting the latter in the line *AB*, Fig. 1. Draw the line, *EC*, making the angle ϕ equal to the angle of internal friction; also the line, *EB*, making its length equal to d. By assumptions (a) and (b) the pressure will be zero at points *A* and *B*, and it is assumed as a maximum at point *C*.

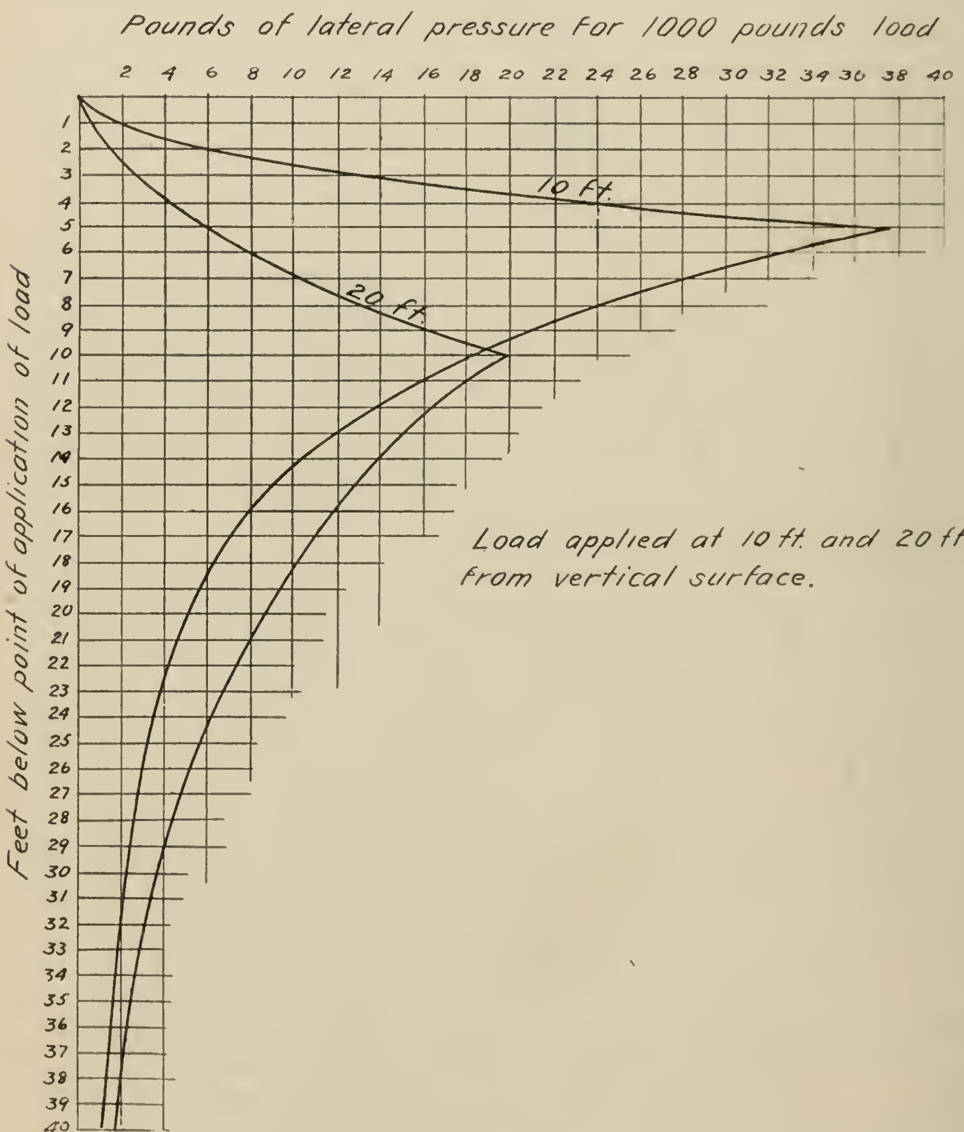


Fig. 2.

Also, by assumption (a), at any distance, d_1, from the point of application, the reduction of effect will be equal to $\frac{d_1}{d}$, and the effective pressure will equal $l - \frac{d_1}{d}$.

Let the total pressure against the surface, AB, be found by Rankine's formula $= W. \dfrac{1 - \sin\phi}{1 + \sin\phi}$, reduced by the effect of the distance of C from E.

$$EC = \frac{l}{\cos\phi}.$$

$$\text{Reduction of effect} = \frac{EC}{d} = \frac{l}{d.\cos\phi}.$$

$$\text{Total pressure against surface, } AB, = P = W. \frac{1 - \sin\phi}{1 + \sin\phi}.\left(1 - \frac{l}{d.\cos\phi}\right)$$

There will be pressure against the surface, AC, due to cohesion along the line (or plane, if W be considered a load per unit of length) EC, and this pressure may be considered as varying from A to C as $1 - \cos\alpha$, so that the unit pressure, p, at any point, D, as compared with the intensity of pressure at C will equal $\dfrac{1 - \cos\alpha}{1 - \cos\phi}$.

Let angle $AEB = \beta$, then will.

$$\cos\beta = \frac{l}{d}.$$

Angle $CEB = \beta - \phi$.

Similarly, the pressure may be considered as varying from B to C as $1 - \cos\alpha_1$, so that the unit pressure, p, at any point, D, as compared with the intensity of pressure at C will equal $\dfrac{1 - \cos\alpha_1}{1 - \cos(\beta - \phi)}$

The summation of the pressures against each unit of height will equal the total pressure against the surface, AB, or, if p be given in terms of the intensity at C,

$$P = C\Sigma p,$$

whence, the pressure against a unit of height at C is

$$C = \frac{P}{\Sigma p},$$

from which the distribution of pressure over the surface, AB, may be found.

This result is not offered as a final or adequate solution of the problem, but as an effort to arrive at some rational method of de-

termining the probable lateral pressure exerted against a vertical surface by a vertical load at a greater or less distance, and the distribution of this load over that surface.

The values of both d and ϕ will vary with the consistency of the soil, and d, especially, will be determined largely according to the judgment of the individual.

As an illustration of the results of this method, and without implying that the values are worthy of adoption, I have assumed in the figure an angle of 26° 30′, equal to a slope of 2 to 1, for the angle of internal friction, and if a distance of 100 ft. be assumed for d, the curves of pressure for load applied at distances of 10 and 20 ft. from the vertical surface will be as shown in Fig. 2. The area included between the curves and the vertical line representing the surface will equal the total pressure against the surface.

THE RELATION OF THE STATE TO THE PRACTICE OF ENGINEERING

TOPICAL DISCUSSION, APRIL 15, 1912.

Hydraulic, Sanitary and Municipal Section.

C. B. Burdick, M. W. S. E. (Chairman).—We are about to try a new departure in the Western Society of Engineers, at least in the Sanitary Section, the conducting of an informal discussion. There is no set paper for this evening, but we have selected for our subject, "The Relation of the State to the Practice of Engineering," using the word *State* in its broad sense including all departments of Government,—National, State and District. We want to give everybody a chance to be heard upon the many questions involved from the many viewpoints of those present.

Engineering is a product of civilization. It seems to be very closely related to the increase in the population of the country and the gathering of the people in cities; and being a subject so closely related to the people, the people have naturally taken an interest in the practice of engineering, and we hear much these days of laws which have greater or less effect upon our profession. As you all know, for many years law and medicine have been governed by license. I have little doubt that engineering is as vitally related to the public welfare as law, and in many cases, as engineering applies particularly to life and health, perhaps fully as much as the practice of medicine. So it is not to be wondered at that people take an interest in the matter and want to exercise more or less supervision. The practice of engineering has touched the public in possibly three points. First, the matter of health, next, the matter of public safety, and, third, the matter of economy in public expenditures, and we as engineers in one way or another touch, and are vitally interested in, all of these matters.

It will be necessary, in order to promote discussion, I presume, to call upon a few of the members here tonight, and I will ask that the discussion be led this evening by the recently appointed engineer of the State Water Survey, Mr. Paul Hansen.

Paul Hansen: In considering the extent to which it is proper or advisable for state boards, bureaus and commissions to give out free engineering advice, it is convenient to consider these bodies as of three classes, namely:

(1) Those which have supervisory powers in local matters.

(2) Those which exist for performing certain administrative functions relating to purely state business, and

(3) Those which are educational in character and exist for the purpose of giving advice to all applicants.

Among boards, bureaus and commissions having supervisory

powers in local matters may be included, among others, state boards of health, state public utilities commissions and state bureaus of factory and mine inspection. The functions of such state bodies as these, should be determined in the light of one of the most fundamental principles of our republican form of government, namely, that there should be a maximum of local self government consistent with the protection of life, liberty and property. Putting it differently: the people should have every opportunity to govern themselves and whether they do or do not govern themselvs wisely does not enter into the question, except to the extent that there shall be protection of life, liberty and property.

State boards, bureaus and commissions which have supervisory powers only, should have power to investigate all matters within their special sphere having an intercommunal character or involving the state at large, and when unsatisfactory conditions are found they should have power to demand their correction. Though the central authority should demand correction of certain evils, the actual determination of the means for correcting such evils should be left as much as possible to local authorities, for the direct taking over of local affairs is warranted only in great emergency. Consider, for example, the matter of protecting life and property and maintaining order—the state militia interferes only when the local police are hopelessly unable to handle a situation. The same is true of state boards of health—ordinarily, local health regulations are left to local health boards, but in times of great danger from epidemics and when local boards fail to handle the situation, the state board may step in and take full and direct charge.

Among those state boards, bureaus and commissions which exist for the purpose of performing certain administrative functions relating to strictly state business, are state prison boards, state insane hospital boards, highway commissions, railroad commissions, etc. These bodies exist solely for the purpose of conducting the business of the state that is practically independent of local affairs. They use state funds for state purposes, though frequently localities are indirectly benefited and sometimes there is more or less cooperation with local authorities to their mutual advantage. Cooperative work does not involve giving away anything on the part of the state, but where there is co-operation on harbor, highway or canal work, the engineering may properly be done by the state engineers, but the locality should have the right of being represented by its own engineers if it so desires.

Among those state boards, bureaus and commissions that may have purely advisory functions, may be included state geological surveys, state universities, agricultural experiment stations and highway departments. The question as to how far the state is warranted in giving free advice, especially along engineering lines, is a very perplexing one. The people of the state have an undoubted

right to tax themselves for the maintenance of all kinds of state advisory bodies. For the development of the welfare of the state it may be quite essential to have men employed by the state to gather data and freely give out advice along some lines; for example natural resources, agriculture and health. On the other hand, good business considerations place a limit on the extent to which free advice or other services should be indiscriminately given. It would manifestly be unwise to maintain a state engineering department to design and construct local waterworks and sewerage systems, or a state architectural department to design and construct local city halls and other buildings, however advantageous the latter would be in improving on some of our local architectural efforts. Such a policy would mean grossly unequal taxation for the reason that the state at large would be paying many thousand dollars for benefits that go to a few communities only. This policy becomes doubly unwise when the locality may readily select engineering and other assistance from a large number of very competent men in private practice. Failure to select a competent engineer is purely a local affair, like inefficient self government, and must not be interfered with unless life, liberty and property are endangered.

Some state boards, bureaus and commissions have all three functions, supervisory, administrative and advisory. Among these are state boards of health. Because of the engineering characters of many problems presented to health boards, a number of such boards now maintain a more or less complete sanitary engineering department. It is with state sanitary engineering departments, and with state engineering departments having similar functions, that I am most familiar, and therefore I desire to confine the remainder of my remarks to a consideration of free engineering advice by such departments as these.

In general the function of a state sanitary engineering department should be primarily supervisory rather than administrative or advisory. It should be in the position of regulating matters that have an intercommunal relation pertaining to health and sanitation. For example, where undue stream pollution is found, it should have power through its appropriate board or commissioners to require a correction of the evil. The manner of correcting the evil should be left to local authorities, subject only to review by the state authorities. This assumes that engineers must be locally employed; in fact the central authority may fairly stipulate that engineers be employed not only to design and construct necessary works but to represent the local interests in dealing with the central board. State engineers are not necessarily infallible and review of their investigations and decisions by locally employed engineers is a wholesome procedure.

The administrative work of state sanitary engineering departments in connection with purely state business, where it exists at

all, is limited to the preparation of plans and specifications and the superintendence of construction of sanitary engineering works at state institutions. It is quite legitimate for state sanitary engineering bureaus to carry out work of this sort, but lack of adequate appropriations renders it generally impracticable to do so.

The matter of giving out free engineering advice, though secondary to its supervisory functions, is still an important branch of the work of a state sanitary engineering department. This free advice, however, should not take the form of preparing plans and specifications and superintending construction, but should relate only to general matters. A few concrete examples will illustrate the circumstances under which free advice may properly be given.

Suppose there arises a problem involving treatment of wastes before discharging them into a stream, the solution of which problem has no precedent. The department must then carry on experimental work for the purpose of informing itself as to what may be properly demanded. Some maintain that the burden of experimental research should rest on the community, corporation or individual affected, but my own experience leads me to believe that in many instances this would be unjust and confiscatory, whereas the state can carry out the work efficiently and comparatively inexpensively, especially if it has an already established experimental station. Where local funds are available, independent or co-operative experimentation should be encouraged. At any rate the performance of experimental work necessarily leads to the giving of free advice by the state department, and the giving of this advice sometimes loses a client for the consulting engineer.

As another example, suppose that the state sanitary engineering bureau discovers a water purification plant that is not being properly operated, and further finds that conditions are such that the local authorities cannot or will not employ expert assistance. In such a case I submit that the bureau would be very remiss in its duties did it not at once carefully examine the plant, place it upon a correct operating basis and instruct the caretakers in maintaining correct operation.

While state bureaus of sanitary engineering give out more or less free engineering advice, it must be borne in mind that a great deal of such advice is of special benefit to the practicing engineer. For example, state sanitary engineering bureaus are in a particularly favorable position for gathering and compiling information relating to a great variety of subjects, and here again the departments would be remiss did they not take advantage of such opportunities and publish the results of their findings. These data will not only be of assistance to local officials but they will be of far more service to practicing engineers as a fund of information; witness the reports of the Massachusetts State Board of Health.

Summary—To summarize in the briefest possible terms, it may

be said that a central department of sanitary engineering should regard itself as the protector of the public at large and should not feel at liberty to expend its funds and time in freely advising communities, corporations and individuals when local expert advice is available. It should encourage and even require the local employment of practicing engineers, in order that the problems may be attacked from all points of view and that the locality may be adequately represented. It often happens, however, that a proper consideration of some problems presented to the central department involves expensive experimental investigations, the results of which are given as free advice to communities, though such advice need not and should not include the preparation of plans and specifications. A state sanitary engineering department should also avail itself of the favorable opportunities which it has for making inquiries relative to sanitary engineering practice along various lines for its own information, for the information of the communities within its jurisdiction, for the information of the engineering profession at large and for the purpose of stimulating a demand for work conducted along thorough-going engineering lines.

Finally, I wish to state that what we are after are results in the vital matters of protecting the public health and improving sanitation. If this necessitates giving out free engineering advice, then we will give out free engineering advice, but taking the activities of state sanitary engineering departments by and large, they are instrumental in bringing the competent practicing engineer far more work than it deprives him of.

Mr. Burdick: As Mr. Hansen has said, no unimportant part of sanitary knowledge has come through the experiments of the Massachusetts State Board of Health, and this it seems is a field where the state can accomplish something that it is practically impossible to accomplish in any other way. No private practitioner often, if ever, has the opportunity of spending the money and making the valuable experiments, in sanitary lines particularly, that have been made in Massachusetts. It seems to me that this is one of the most important fields that can be entered. While we are on the subject of sanitation we would like to hear something from Mr. Pearse, who is working these days entirely along experimental lines.

Langdon Pearse, M. W. S. E.: The subject has lined itself up in my mind according to two methods of procedure. *First,* where the state or federal government undertakes large works of such nature that private capital would not be interested; as, for instance, the reclamation work of the Federal Government, the Hoosac tunnel which was started originally by the State of Massachusetts, the Barge Canal in New York, and other works of a similar magnitude, There it seems proper that the state should step in, organize an engineering corps and carry the work to completion in every detail.

Second, where there are certain administrative details that have to be met, as Mr. Hansen has outlined, that is, by state boards of health or public service commissions, which are now becoming so common. It seems to me the functions are all advisory there. As a rule, there is not the time nor the facilities for a state official to go in and actually attend to all the details. Therefore it is highly proper that the state bodies should urge the employment of competent advice first hand to study every detail of a local problem. Long distance administration, like absentee landlordism, is not satisfactory. I feel, as long as we do not have federal ownership or control of all the public utilities and the like, that it is not the function of the state, or, for that matter, the Federal Government, to go further than to act in an advisory capacity, except in the construction of the large works mentioned.

As regards the experimental field, I believe that it is one where the state can spend money to advantage—not only to its own advantage but to the advantage of engineers, as a class; for instance, the work we are doing for the Sanitary District of Chicago to organize the operation of its sewage disposal scheme, find its limitations and collect the data, not only for the design of our plants but also of material service for the design of plants under similar circumstances elsewhere. It is of distinct benefit to the country generally, aside from what benefit the City of Chicago or the engineers engaged upon it may get. I feel that in that case we are somewhat akin to the state situation. To a certain extent we also meet this same problem in the administration of our sanitary affairs. We come in contact, for instance, with the packers, who are polluting the river and canal to an extent not contemplated by our charter, and there are other industrial wastes. Certain conditions exist that by experiment we can probably arrive at the best means of remedy. We do not think that in such cases we are usurping any functions, because, as Mr. Hansen has said, we already have an experimental station that is carrying on just such work and can take on a small additional load without very much internal friction.

The situation in other countries, I think, is governed somewhat by the degree of governmental control. I understand that in France work carried on by engineers is more largely under governmental control than in this country or in England. In Germany, an engineer, in order to practice, has to have a diploma from a recognized school and must pass well up in order to get a good place. The work is carried on more or less systematically with a definite civil service, so that the conditions are not like those in this country. In fact, in Germany the business of being a Mayor of a town is a profession. If a man is a good Mayor in one place he may be called to a larger town, and so it is with the engineers. We can not imagine such conditions in this country. In England the organization of large work, as I have followed it from a sanitary standpoint, is largely controlled

by parliamentary authority. There is a royal sewage commission, but its functions are largely advisory, comprising, however, the collection of an immense mass of data, which is gradually boiled down and digested. This comprises not only the operation of sewage plants, but also the opinions and practice of many engineers. Regulations are laid down that must be adopted for further work. I do not think it is on record that the Royal Sewage Commission builds or actually designs them. Certain general lines are laid down to be followed. It seems to me, at least from the standpoint of my own branch of engineering, that is, the sanitary line, that this is the logical way to do. The state or federal engineer often has a somewhat wider range of effort and view, covering perhaps a better perspective of the workings of different plants under different conditions. He is, therefore, able to give the perspective that the local man often wants, in adjusting his ideas to a definite problem. I personally feel that the advisory capacity is therefore the most important.

J. W. Alvord, M. W. S. E.: I have not come particularly prepared to speak on this subject, but it is one to which in times past I have given a good deal of thought. I have passed through certain changes of opinion with regard to it, which may be of interest as illustrating its many sidedness. To a considerable extent I think the question of state control of the professions and the work of the engineering profession in particular, reaches into the roots of our governmental problem, the problem of democracy that we are working out in this country. I never realized so fully what statesmen meant when they said that in its government this great American republic was an experiment, as I have in reviewing some of these more concrete problems, such as this question of state control of professional work.

The first thing which is apparent to a man who thinks and observes is the fact that oftentimes things are not going just right; there is always something that should be bettered. It may be municipal government; it may be in a question of inefficient legal procedure; it may be in the wasteful mismanagement of our public funds; it may be in the ill design of our dams and bridges; it may be that there are so-called engineers who are practicing engineering whom we personally think are not fit to practice.

This is the first phase that comes to us; instinctively we reach out for a remedy. As engineers, for instance, our first impulse is, how can we keep the public from being imposed upon by incompetents, and naturally the suggestion follows, let us pass some kind of a law to stop them, and then we organize and endeavor to get some kind of a law passed to license or regulate the practice of the profession.

But the next stage of thought comes to us when we notice the result of legal restrictions to professional work, and especially the

results of strict governmental control, as it is carried out in certain states here, and more completely abroad. We notice that there are certain dilemmas resulting from creating professional standing or rooting out social difficulties by law. It is rather difficult, when you come down to actual language, to frame a law so wisely that it will, for instance, weed out men who are incompetent to practice their profession; and the more you study these difficulties, the more you will find it is quite impossible to overcome them in any simple way. We know that we often come up against some restrictions in those legal enactments that hit us personally, and we resent the injustice of it, as, for instance, the Architects' License Law in this state, which virtually prohibits an engineer from building not only a building but a reservoir or a tank, unless he takes out an architects' license. Here we discover that the law, however well it looks at the start, does not fit.

Finally it dawns on us that, broadly speaking, in the progress of civilization things very often right themselves. The art of learning to live together in large masses or as communities is not the result of laws; laws are the result of learning how to live together; that is, experience as an educator is sometimes more discriminating and more perfect in its working than any law that we can devise.

Personally, I have been through some of the phases that I have just described. In my early life I was largely engaged as a city surveyor, and used to go through all the worries that competition in the surveying business brings. Early I noted that there were men in the surveying business who seemed to me to be so poorly equipped for their calling, that it seemed to many of us that for the protection of the public, they ought to be shut out. Therefore, I became enthusiastic about surveyors' licenses, and, with quite a number who felt the same way, worked for some years to try to induce the legislature of the state of Illinois to pass a surveyors' license bill. We went down to Springfield for this purpose a number of times, but we found that they looked at us suspiciously. They said, "What is there in it for you." Some of us stopped to think. We had supposed we were working for the good of the public. Perhaps there was something in it for us. At any rate, we did not succeed in making any great impression on our legislature, much to my disappointment then and my relief since. We devised several laws, but we could not seem to devise any law, when we came to read carefully every line and section, that would certainly operate the way we wanted it to; that is, shut out the fellows that we thought were incompetent and leave us, whom we naturally supposed were exceptionally competent, in full possession of the field.

A little later I became interested in a broader field, sanitary work, water supplies, sewerage disposal, and I became enthusiastic about enlarged powers for our state board of health. In Massachusetts, the state board of health, about 1890 (as perhaps you all

know), was equipped with very drastic powers, sufficient to step in and order any community to care for their sewage or obtain their water supply by just such methods and with such details as the state board would approve, and no other, and I thought that was the very ideal. It seemed to me where the public health was involved, if any line of investigation justified drastic measures this field certainly seemed to warrant them. One might easily imagine that a poor lot survey would only affect a few individuals, or a relatively small amount of money, but here was a great public health question. It did seem to be a subject that ought to be regulated by the state. So, through the engineering societies again, we formed committees and went before the legislature and spent a good deal of time and a good deal of money trying to get legislation to broaden the powers of our state board of health, and to put into their hands something like the drastic powers the Massachusetts state board of health had at that time. That effort lasted several years, and finally resulted in the creation of our State Water Survey, but without drastic powers. I feel now, in the light of all that has developed, that it was well we failed to obtain what we then desired, and think the legislature was wise to grant only a modified demand. But other states did adopt rigid supervisory measures. Ohio followed Massachusetts, and, later, other states, Pennsylvania, notably, within the last five years.

Watching closely the results in those states where the boards of health have had these large powers, I observed there began to arise restlessness and discontent among local authorities as well as among the best practicing engineers engaged in sanitary work. It could be observed also that in certain notable cases there was not that open-mindedness to progress, by the state authorities, that it would seem ought to be shown by a great authoritative board. Responsibility seemed to beget prejudice and narrowness, communities began to resent the fact that they were not allowed reasonable latitude in their choice of methods. To cite specific instances: About the time when we began to be interested in so-called septic tanks, the Massachusetts state board of health pronounced septic tanks as undesirable, and today, with over 300 so-called septic tanks in quite successful operation in other parts of the country, there are practically no septic tanks in the state of Massachusetts, due to the refusal of the state board of health to approve of them. I may be mistaken, but it has seemed to me that this board has of late years shown prejudice against any form of improvement that did not originate within its own control. I began to feel that there was something wrong about drastic control, even of so important a question as public health, if that control was to hinder or hamper sanitary progress. It has always been clear to me, however, that there is a function that the state can exercise to the great advantage of the community, and that there must be some proper boundary

line between the advantageous functions properly belonging to the state and the proper liberty of the local community in methods and means. I have come to the conclusion, as a result of a good many years of study and thought on this subject, that the functions of the state should be largely confined to educational work, to experimental work, to co-operation with the individual community in its sanitary problems, and in some cases at least not only to advice and assistance, but emergency measures and moral pressure where communities persist in menacing the outside world, as well as themselves, by ignorance or neglect of obvious sanitary precautions. I believe it best not to go much farther than this. When the state does go farther, it assumes responsibilities it often does not know how to meet. It practically assumes all the responsibility of the local community, for instance, when it specifies the details of water filtration, sewage disposal, or the cross-section and foundation of a dam, and it certainly relieves the private practitioner of any responsibility for the design when he becomes in effect a mere draughtsman, who is reduced to the necessity of carrying out the orders of a state functionary.

Now this view of mine has seemed to some friends in public health work, to be rather a retrograde step, but I can not help noticing that in every state, in this country at least, where drastic control has been in operation for a sufficient time by state boards of health—I speak of public health because I have watched that department of public control more closely—there has been a decided reaction, after a certain number of years, against such drastic control, and usually a successful reaction.

As to concrete examples. The state board of health of Massachusetts to my mind did excellent work in their early years in experimentation. They increased our knowledge of sewage filtration, and, what is more important than that, they increased the general respect for public sanitation in our country. But, unfortunately, they got to a point where they seemed to be so satisfied with their achievements that they did not care to recognize progress from any other quarter, and appeared to regard everything new that was proposed from other sources as more or less of a reflection on their position.

You may be surprised, but I understand that the city of Lynn, Mass., has desired for some years past to install a mechanical filter plant for its water supply, as recommended by one of the most prominent sanitary engineers in this country, and of the type which we use so extensively and universally here in the West, but a type, unfortunately, not favored by the Massachusetts state board of health; and the board refused to permit the introduction of that type of filter in the city of Lynn. The city has applied to the legislature, I believe, for permission to install a filtration plant of that character. It does not seem to me, speaking broadly, that that

sort of control is quite justified. I cannot help but feel that the state board of health of Massachusetts is standing in the light of progress to take such an unfortunate position.

Take another instance; I understand the city of Fitchburg, Mass., desires at the present time to install a sewage disposal plant, including, among other features, sprinkling filters. Sprinkling filters are generally regarded by sanitary engineers as one of the successful modern appliances in sewage disposal work. They did not, unfortunately, originate with the state board of health of Massachusetts. They came to us from England. Whether rightly or wrongly, the state board of health of Massachusetts opposes the introduction of a sprinkling filter in the city of Fitchburg, and I understand that city is about to go, or has already gone, to the legislature for permission to install such a filtration plant. I might go on and illustrate a number of cases of that kind, which to my mind indicate that municipalities and practicing sanitary engineers are getting restive, not only in Massachusetts, but in other states, over such drastic control and obstruction to the general advancement of engineering methods. I think it is fair to say that in Ohio, where they had, for about 8 or 10 years, a drastic law for regulating sanitary engineering, there have been excellent results, particularly from the educational phase; but there has been, nevertheless, some arbitrary procedure, followed by a reaction against such control, due to a feeling on the part of the municipalities and on the part of the practitioners, that such control is altogether too arbitrary. That reaction has taken the form, I understand, of reorganization of the board of health there, and, if I am not misinformed, some change in the law which created this power.

The state of Pennsylvania adopted, about five years ago, a law creating drastic control by the state board of health, and naturally it takes some years for the full effect of such a law to be understood, but it seems to me there is already evidence of growing restlessness in Pennsylvania over some of the state regulative measures as to sewage and water supply.

One recent instance with which we are all familiar is the sewage disposal of Pittsburgh, ordered by the state board of health at an expense of some thirty or forty million dollars. The city of Pittsburgh has employed some of the most eminent sanitary engineers in the country, who report adversely to such a project, and state that in their opinion Pittsburgh does not now need, nor will need in the near future, any such disposal plant as has been ordered by the state board of health. And, by the way, one of the difficulties of control by state boards, it seems to me, lies in the fact that such positions are largely in the hands of the medical profession, who have not always been trained to the economical and financial considerations necessarily taken into account in these large problems.

Whether or not this restiveness will be the outcome in every

case, whether such experience will follow, for instance, in public road legislation, in licensing engineering and architecture, or closer restriction on structural engineering such as the approval of precautions in the building of dams, I am not prepared to state; but I rather think, from my experience in observing state sanitary control in the last twenty-five years, that drastic authority breeds discontent and ultimately largely defeats the benefits sought to be obtained.

One may ask, then, what is the proper view of the function and the power of the state? I would say I very closely agree with most of what Mr. Hansen has said here in that regard. I think that the state is serving its highest function most efficiently when it confines its attention to the questions with which the municipality and the private practitioner can not successfully cope. That is to say, the general study of these larger questions, such as pure water supplies, prevention of undue pollution in our streams, the proper disposal of sewage, tests of structural material, the development of the resources of the state and the conservation of such resources. A certain amount of advice and co-operation must of necessity accompany all these lines of work. Advice may be safely given where it is not likely that the community would seek professional advice at all; advice as to dangers that communities run in public health is always desirable; advice and co-operation with the practicing engineers who are endeavoring, as well as the state, to educate the public properly upon these questions, is proper. In this way I think the state really exercises its highest function and meets with its best success. Here in Illinois we have excellent conditions so far as our public health is concerned. We have state appropriations for a water survey, and for a general study of the water resources of the state. The state of Illinois will examine water supplies free of cost where communities feel that they want to apply for such assistance, and the state will give that information out in such a general way that it is of the utmost value to all of the practitioners in that line of work. The state will go by request and advise as to filtration of water supplies where they think they are not properly operated, and in such ways co-operate with the local community as well as with the practitioner. We have more recently formed our Rivers and Lakes Commission, which has no very drastic powers, but it has undertaken to give us a great deal of valuable general information about the streams of the state, their liability to pollution, and the dangers to the community that would occur from that pollution.

We have our State Geological Survey, which is devoting itself to the disseminating of correct information about our topography, geology and resources, and is of large benefit to our work.

We have one piece of thoroughly vicious legislation on the statute books,—the licensing of architects. This law reads in such a way as to put engineers out of business were the law strictly en-

forced. This one mistake has been an object lesson and it is a law which should be repealed or amended. It illustrates much of what I have said here as to hampering freedom of thought in professional work, under the guise of protection to the public.

We have also in Illinois an experiment in state highway legislation, which so far has developed into a state highway, bridge and culvert engineering department, doing practically free bridge engineering for the rural communities. This has resulted in good so far as it has developed a field of engineering in the state which hitherto did not exist, and in which no private practitioner could hope for work. The instruction of the smaller communities in the value of good bridge engineering has been educational and valuable, but it may easily grow into an evil, if not wisely directed and controlled, and is to my mind a source of future danger.

I have no sympathy with the petty jealousy which would criticise state control, because in some cases it may deprive a private practitioner of a few small jobs, for I believe, in a broader view, the advantages to the engineering profession by state departments, conceived on a broad co-operative basis, far outweighs any disadvantages usually encountered; but so soon as the state educational work is thoroughly accomplished, and, for instance as in this particular case, the rural communities of the state learn what good bridge and culvert work is, the attention of the highway commission should be directed to other and more useful educational work on the bettering of roads, leaving the minor bridge work of the state to be done by the private practitioner, where possible.

Speaking generally, I believe that the state can well afford to increase its appropriation for all these purposes above mentioned, and can also well afford to omit any drastic powers (with the exception of the control of epidemics and quarantines), that some of us in the past and others of us in the present would like to endow it with. We can not progress as a great people faster than the general average of intelligence, and when the general average of intelligence arrives at the conclusion that we need skill and experience in our public matters, then we do not need laws to enforce those conclusions. That is the view which I have reached as the result of my personal experience with state relations to professional work, and it seems to me to be the solution toward which we are inevitably tending, whether we wish it or not.

Mr. Burdick: The discussion so far has been almost entirely along sanitary lines. Certainly the state touches engineering upon a great many sides. I am going to ask Mr. Allen to say something about the relation of the state to engineering in general and his line of engineering in particular.

Andrews Allen, M. W. S. E.: I have given the subject for the evening considerable thought during the last few years in connection with my work as a member of the legislative committee of

this Society, and I would like to add a word this evening principally from the standpoint of structural and bridge engineering.

In discussing the relation of the state to the engineering profession and the question of licensing engineers, we have to take things as we find them. That is to say, we can not organize a community with a brand new body of laws, but must take things as they are, and with the means at hand work through these conditions to better ones if we can. Personally, I feel, as Mr. Alvord has so very well expressed it, that as engineers we can not afford to do anything to limit freedom of action and of initiative. But when action and initiative are already limited, even an engineer's license may be a step in the direction of freedom.

In structural engineering we have a condition that is quite anomalous and I think exists in very few other states of the Union. About ten years ago, while the engineering profession must have been asleep, the architects stepped in and took the entire ground from under the feet of the structural engineers. At the present time it is contrary to law in the state of Illinois for an engineer, unless he happens to hold an architect's license, to build any structure having "foundations, walls and roof." We are doing it, as far as that is concerned; but we are doing it in open defiance of law and we are allowed at present to do this because the architects do not know how to build all kinds of structures with "foundations, walls and roofs," and leave us alone rather than try conclusions. But where engineering begins to verge on the special preserve of the architect, as in factory buildings, we find that the architects maintain their ground very jealously. Then, in cities like Chicago where the state law has been strengthened by local ordinance and enforced by the machinery of the building permit, and where an architect's seal is required on the plans of an 8 ft. by 10 ft. coal shed, evasion of the law is made possible by the scrub architect who picks up many dishonest dollars by signing plans which he has had very little hand in preparing.

Now in regard to the conditions existing under the present law, the facts are that architectural engineering work is for the most part very badly done, unless an engineer is connected with it. The vast majority of architects are not engineers and do not want to be. They do not understand engineering and rather look down upon it and, as a consequence, the engineering in ordinary building work is usually very rudimentary and inefficient, often extravagant and frequently unsafe.

I think that the Western Society of Engineers, representing the engineers of this state and the West generally, should go into this matter in a constructive and sane but efficient way. The present conditions must be removed. We can not suffer a great profession like our own to be debarred from a very important part of its business and be forced to practice it in defiance of law or under

the name of another profession. This matter ought to be put before the engineers of the state and the people of the state as strongly as possible. We can do just two things. We can make a strong attack on the present architects' license law with the object of wiping it off the statute books and leaving the practice of engineering and architecture free, or we can work for the enactment of a structural engineers' license law. It is my firm opinion that the latter course is the wiser and the easier of accomplishment.

In regard to the form which an engineer's license law should take. The architect's license lāw at the present time is administered by a state board, which issues licenses on a "school boy" examination covering three or four days at Springfield. The only ethical or legal basis for a state license for an architect is as a protection to the public against unsafe and unsanitary construction, but comparatively little attention is actually paid to such matters and a good deal to mere draftsmanship. The well coached school boy or the "Beaux Art" man gets through and the competent engineer fails to pass. If this license law is to be our model I am against it. I don't want to see schoolboy examinations and am not in the least convinced that they are necessary. I believe that it is possible to devise an examination that will test the candidate's general knowledge of engineering principles and will then examine the work he has actually done and investigate his experience and record. As a matter of fact the faults of the present architects' license law are more in its administration than in the law itself. The commission has full power to conduct such tests as will establish, in its judgment, the fitness or unfitness of the candidates for an architect's license. If a certain kind of examination or test were required, a rejected candidate would have the right to appeal to the courts, and this might lead to a practical nullification of the law or at least to constant and harrassing litigation. Our law must not only be wisely drawn, but wisely administered and it is certainly within the province of the Western Society of Engineers to suggest rules for the administration of the law, when passed, which will give it a broad constructive effect and will be almost as binding as if they were a part of the law itself.

A license for engineers would have one great advantage. It would define our profession and give its members a legal status through which their public duties could be enforced. This would be true even if the license were granted as a mere matter of form to anyone reasonably qualified to practice the profession. The term "engineer" at the present time is shared not only by a great many kinds of engineers, but by stationary and locomotive engine men. Anyone can call himself an engineer, and the public naturally demands for its own protection that a profession should be defined and brought under the law before granting it any exclusive or special privileges, or allowing it to share such privileges with an-

other profession that has already been defined and brought under legal control.

The legislative committee of the Western Society of Engineers has been at work upon this problem for the past three years. We attempted a year ago to insert some amendments in the architect's law. We were met with very strenuous opposition from the architects, but after fighting the matter out with them finally came to an agreement that if we would keep our hands off their law they would help us to obtain a license law of our own.

At the present time the matter stands as follows: Largely through our efforts the last legislature passed a law appointing a commission for the codifying of the state building laws. This commission has now been appointed and contains two of our own members, suggested by our Board of Direction, and two other members who are engineers as well as architects, so that the commission is extremely friendly to engineers as a whole. The idea now is to classify buildings in some rational way upon the basis of their uses and structural features and to provide general and rational structural, sanitary and economic requirements. Then follow with a bill licensing engineers on some general basis and empowering licensed engineers to design buildings of certain classes; also requiring their employment on buildings of certain other classes.

At the present time the word engineer has no legal significance. Anybody can call himself an engineer. It means nothing, and that is what the architects threw up at us when we began to discuss this matter with them. They said "Your profession is nothing. Your name doesn't mean anything. How do you know it does not describe a stationary engineer or a locomotive engineer? Then you have so many kinds of engineers. You can not empower an electrical engineer to design a skyscraper." Our idea in the engineer's license is to try to make it just a license to give him a legal standing, to hold him responsible for his acts in compliance with this building code.

As far as the building code is concerned, the commission is attempting to collect data from all over the country and to formulate a wise and conservative skeleton building code, which will cover the main features of building requirements for use throughout the state and which will have a tendency to bring the average building construction up to decent requirements. Such a law will undoubtedly require some kind of a building permit, and the engineers must remember that the doom of the structural engineer will be completely sealed unless an engineer's license law is passed at the same time. We must insist upon the one as our price for the support of the other.

When we come to the other phase of the question, looking at it from the standpoint of our own profession, a very serious question arises as to the condition of the monopolized or closed profession. We see examples of this everywhere: in the

profession of medicine especially and to some extent, for that matter, in architecture. We see that the tendency in those closed professions is, you might say, "ingrowing," that is, they do not progress as open professions do. The open professions have plenty of incompetents in them, but they are alive and active and they grow. Closed professions get into the hands of the ambitious and unscrupulous members, are usually run as private monopolies for their own benefit, and the public aspect of their work is gradually lost sight of. So far as the profession of medicine goes, you know how that is; how the veil of secrecy is thrown around things that they do not understand and how the mistakes of the profession are covered up, and how the dead tell no tales. We all know these things and we do not want anything like that to happen to our profession. It is too great, perhaps the greatest of all, when you come to look at its wide field and its intensely public interest.

This is the phase that I was asked to speak of this evening, and when the question comes up, perhaps next year, as to whether you will vote to recommend the action of your legislative committee on the license bill and other bills that may come with it, I want you to bear this in mind and think it over. If we offer a bill to license engineers, I want you to remember that it may not be what we would choose in an ideal community; but that it is what those who have had the matter in charge have, after a long discussion, thought would be the lesser of the two evils and perhaps the only way to give our profession the standing to which it is entitled in this state.

F. L. Stone, M. W. S. E.: I have been very much interested in the development of state and government functions in the practice of engineering. This Society owes an expression of appreciation to Mr. Hansen, for expressing so clearly and fairly, views as to the functions of the state in engineering practice, which will be generally endorsed; namely, they should be protective, educational and experimental largely. The state has a function in protecting communities against each other, without interfering with or removing the local rights of either community to take care of its own troubles or problems in the way that seems best, so long as it does not encroach on the rights, health or safety of other communities.

In highway work there are separated communities connected by intervening territory where local organizations are in no way equipped to provide means of communication between such business centers, and where it might not be the province of either of the communities to construct or to maintain a highway connecting them. Here the state can aid and direct in planning, promoting and constructing roads which are of general benefit and which otherwise could not be accomplished. Local communities should solve their own local problems, employing such advisory help in their own improvements as seems best. Experimentation and the

gathering of data concerning improvement work over the country are of vast importance to communities in handling their own work, and are of great benefit to engineers generally.

As to any benefits that might come to the engineering profession from a state license, I am personally in very great doubt. Our standing as engineers must come from quality within the profession and an education of the public as to differences in value of engineering service. Development must be by growth. Professional standing by legislation is inconsistent with the growth and open field of the profession. I believe that but few of the incompetent and still fewer of the unscrupulous would be eliminated. I believe that the standing of the engineering profession must develop through individuals and societies. A good example is furnished by the American Railway Engineering Association, where the engineers for the railroads have formed an organization for comparing notes, ideas and results of individual experiments, and discussion leading to a recommendation of the best practice or what is considered by the majority of engineers as good practice. If we will agree as to what constitutes good practice, and then be guided in our special lines of work by such standards, we will become known and will be looked to by the public for advice on problems requiring the employment of engineers.

L. K. Sherman, M. W. S. E.: We have in this state connected with engineering, or related more or less to the practice of engineering, a state board of health, the state water survey, state geological survey, the state highway commission and the rivers and lakes commission. The duties of these commissions may be advisory or they may be supervising and they may be mandatory. These points have been touched upon by the previous speakers and I heartily agree with them as to these duties. I am in favor, as they are, of giving advisory powers and the powers of supervision, and I also agree with the previous speakers in limiting the mandatory powers. I do not think that in this state we should repeat the order of the state board of health in one state, where they, by a blanket ordinance, compelled every town to install a septic tank. I do not think we want to repeat the action of the state board of health in Pennsylvania that has been referred to.

There is another point, that has not been covered by the previous speakers, as to the duties and powers of state commissions. That is what might be termed the executive duties; that is, whether a state commission or a state board should have the right and power to actually go out in the field and do the engineering work. For instance, we are agreed, I think, that we do not want a state board of health to issue mandatory and blanket instructions as regards details of solving the sanitary problems. I think we are agreed that we would not delegate to, for example, the state highway commission, the right to order a certain municipality to improve

its roads whether that municipality saw fit to or not, however desirable that road improvement might be. The other point in question is this: Should the state highway commission, should the state water supply or the board of health, if requested, actually get up plans, do the engineering, if you please, for these communities? That is a question that I answered in the negative at one time, but I fail to see how we can draw the line. I fail to see how we can logically stop there. We may feel, referring, for example, to the state highway commission, that it is out of their place, it is not their function to furnish plans, to do the engineering work in direct competition with private engineers. But where are you going to draw the line? Here we have a city engineer who designs the bridges, the pavements and the sewers for a city. There you have a county or maybe a district with an engineer for several towns. You can go still farther, if you please. Why would you stop several cities, maybe several counties, if they wish to employ the same engineer? They have that right. It is only one step further to making it a *state* engineer who will furnish the plans, the specifications and the engineering to any and all cities in the state if they wish it. Understand, I would have this optional. They could get this service if they wished. There are probably some here who do not agree with me on this, but I think that is a logical view of it, and certainly, so far as results are concerned, in the few instances that have come to pass—take, for example, the state highway commission—the results of their work can not be questioned. They have taken up a field that heretofore has not been covered by private engineering practice; the small highway bridges, and that sort of work, they have placed on a sound, scientific engineering basis. Their results are certainly commendable. I happened to run across two instances within the last month. One was the letting of contracts by the old method; contractors coming in and bidding on highway structures, submitting their own designs. The other was bidding according to the designs furnished by the state highway commission. In the latter case they will have a first class job at a reasonable price. In the former case my opinion is that the contractor who got the job has it for a structure designed with a factor of safety of *one*.

A. N. Johnson, M. W. S. E.: It is a fact that possibly you all know, that in the phase of the state's activity in engineering work which applies to highway work, it has proved to be the taking up of the engineering practice and engineering management of a kind of public work which had not been taken up by engineers, speaking broadly, and especially as it applies to the rural or country roads and bridges. This is so because of the attitude of the people themselves toward what they regarded as a proper subject for treatment by the engineer and also perhaps because of lack of knowledge of what the engineer might be able to accomplish.

This point was well brought out some fourteen years ago when

I was called upon to take charge of the first state highway work undertaken in Maryland. So prejudiced was public opinion against the idea of an engineer interesting himself or "butting in" on highway work, that, much to my disgust, when I arrived on the scene I found that the letterheads described me as a "highway expert." That was to get around imposing upon the people the word engineer. Today it is recognized that the engineers are necessary to direct such work.

The conditions here in Illinois, and, in fact, all the upper Mississippi valley, as you know, have presented an expenditure of public money that unquestionably would have been better and more efficiently made if done under engineering supervision. Speaking broadly, it had not been under the control of engineers, and the state in this particular has not interfered with or narrowed the field of the private engineer. I will not pretend to say that there have not been cases, where, if the community had not called upon the state highway commission, a private engineer might have been called in. But of the some thousand and more calls that we have had, I can state fairly that there have not been five that I know of where the community would have employed an engineer in any capacity whatever; and as the law says the state commission shall give advice when asked to do so by municipalities and townships, we can not draw any line or say that we will not give this advice. As a matter of fact, in a far greater number of instances in our work, it has resulted in our turning the attention of the local authorities to some practicing engineer as being better able to handle their work than we could.

I think if these conditions had been more carefully looked into and more thoroughly known that the editorials that appeared in the *Engineering News* on free engineering would have been greatly modified. In the first place, it is not free engineering. It is simply the people are paying for it and they ask for the service for which they pay, and, as Mr. Sherman well brought out, there is no logical line that can be drawn between a community closely populated by ten thousand or two million saying we will have our own engineer to do our work, and a similar population, only more widely scattered, saying we in turn wish to have an engineer to supervise a certain feature of our public expenditure.

In those cases which have come under my observation where the private engineer, more particularly on highway bridge work, has been called in, it has often resulted in not much better results to the local community than the conditions which have existed and do exist in the majority of cases today when plans, if any, are submitted by the contractor himself; for the reason that the consulting engineer necessarily first has his fee to secure. If he is to get the fee he has to do the work, and under the conditions under which he must take the work, he usually enters into a competition. The local authorities themselves are not competent to see and understand

that a good engineer, with well considered plans, must be paid a certain amount of money. They usually do not understand or appreciate that point at all. In most instances they will take the plans that are offered to them for the least money or for the least fee. In other words, the public again in this case is practically unprotected, and there is little difference between all the contractors bidding on plans secured in this manner or the contractors themselves offering their own plans.

As a matter of fact the engineer has not been called in by local authorities, so that in this phase of the state's activity in engineering work it seems to me that the state has simply opened up to the engineering profession a branch of work that heretofore has been closed, and while the engineers will not, perhaps, do this work in a private capacity, they will do it in a public capacity. We shall have, this summer, at work in our office, about fifty-five engineers. A few years ago there was no similar field open for employment to them. Today the people are appreciative enough of this class of work or of having this class of work put under disinterested engineering supervision, to now require their employment. So I think the statement can be well sustained that the work of the state highway commission has opened to the engineering profession activities that were before practically closed to it.

But this whole matter should be viewed in a broader light than merely in its relation to the engineering profession. To the speaker it marks a distinct advance towards efficiency in public work, and as in the particular matter under discussion, engineering supervision is productive of better expenditure of public money, so it is evident that whether engineers are to be employed in a private or a public capacity, is a question that will be decided aside from any opinion engineers personally may have on this question. Experience has well shown that wherever the public has a project under consideration, the public should have its own engineer in charge, who is capable either of carrying on the project itself or at least of being able to decide as to the suitability of plans submitted by other engineers, if the particular piece of work is one that calls for high specialization.

In the case of road and bridge work, where the public has a constant demand for engineering services of a certain character, there can be little doubt but that the best way for this to be handled on the part of the public is for the public to have its own engineer. This has been the practice, and is today the practice in all large cities, and, as has been brought out in this discussion, there can in this particular be no logical difference between the advantage gained by a closely settled community and what would be gained by a community more widely dispersed in area.

Ernest McCullough, M. W. S. E.: We are all compelled to admit that the government of the future will be more of a socialist nature than it is at present or than it has been in the past. The

present tendency in the United States is towards a larger measure of democracy, which will of necessity react towards a more autocratic form, and, since the days of monarchies and special privileges are almost ended, the strong autocratic form of government of the future must be socialistic, than which no greater autocracy can be imagined when it is working in its fullness. It is not anarchy, which implies an utter absence of laws, rules and regulations, as so many who style themselves socialists seem to imagine, although they claim to have nothing in common with anarchists. It will be a condition, or state of government, when our every act will be so hedged about with restrictions that initiative will be well nigh lost for the greater number of the people and the mind will be a common mind, the impulse that of the crowd; the product of the work of the brain, as well as of the muscles, of a man will be the common property of the community. When that time comes there will be no necessity for such organizations as the Western Society of Engineers and the question of the state in relation to engineering will not be discussed, for all engineers will be employed by the state. Then the engineer will not have to chase jobs, for the state will find employment for him; if not in engineering work, then in tamping ties, or digging ditches, or something else that his engineering training will have fitted him to do, for in the days of which the socialists dream, no man will be permitted to eat who does not work, and work of some sort will be found for every man. The only work that is expected to have ceased before that time will be the work of the coupon clipper whose busy scissors raise so much discontent in the present time.

Conditions are rapidly approaching the period when a trial will be made of some of the principles advocated by the socialists. Large corporations show that it will be possible to organize the public business on an immense scale, but, strange to say, our government, while continually enlarging its powers and taking on new duties, is trying to break up the big business organizations and force a return to primitive competitive methods. The average engineer in private practice cannot somehow connect the two things. He sees the government trying to create an appearance of competition in large business, with no attempt whatever at adequate control; while in his particular case he has to compete with the government whenever he tries to make a specialty of irrigation or land drainage, highway or bridge engineering. In other words, he is up against the strong growth of socialistic ideas when attempting to practice his own profession, and cannot find employment with the big corporations owning the railways and other big public utilities because he was born too soon to enter their employ, as they prefer young men who can start in at the bottom and grow with the business. In the case of the big corporations the government compels competition but does not enter it, while in the case of the smaller things

it prevents competition by gradually absorbing the affairs that formerly concerned the engineer in private practice.

This of course is merely an echo of the plaints of those who find themselves in the position of the old man who complained that when he was young he had to give up his seat to old men, remove his hat when he met them on the street and honor them in every way, but now that he had reached the age of white hair and few teeth, the old man was out of date and the young man did not treat *him* with the slightest consideration. The time for complaint is of course the transition period in all things, and just now the question of the state in relation to engineering is a burning one for engineers specializing in certain lines of work. The question is, should we not rather, as public spirited citizens, do everything possible to further the work, but at the same time do all we can to guard against certain evils that follow in the train of governmental control and the exercise of governmental authority.

I suffered exceedingly in the west, where I specialized for some years in irrigation and land reclamation, because of the way in which politicians were able to compel the heads of certain departments to send out men to make plans for land owners and supervise construction work. To say that a great many inexcusable mistakes were made by some of the government experimenters would seem like an echo of the cry of "sour grapes" uttered by the disappointed fox in the fable, but the facts are that such mistakes were made by owners thinking they were getting engineering services free, and because the small pay given the boys by the government did not operate to secure the best work. Gradually, however, the accumulation of information on the subject led to a sure knowledge which is now available to all. Some say it has helped the engineer and some say it has had the bad effect of making each landowner his own engineer, after reading government publications, and is relegating the engineer to the post of surveyor and setter of line and grade stakes. This is true in some sections where the time of the employer is not considered to be worth much and his interests are so small that he can afford to putter over trifles. The man of large interests prefers to pay a specialist any reasonable price and be relieved of detail work, other than the signing of checks as compensation for services rendered. The true engineer, however, the man of trained judgment, will never be displaced by the entry of the state into engineering affairs.

So much for the work of the government in the advancement of irrigation and land reclamation work. Another phase of the subject is the extreme danger of bureaucratic tendencies which warp judgment, interfere with initiative, cause needless expense through the red tape seemingly rendered necessary when large enterprises are afoot, and sometimes unduly exalt the detective and inspector above the men at the heads of departments. It is known that Mr. Wallace and Mr. Stevens could not retain their positions at the

head of the Panama Canal work because of the vast amount of circumlocution developed in the doing of government work during many decades. These men were accustomed to dealing with large problems directly but they were not strong enough for the thousands of small men underneath them in the big bureaus at the seat of government. They therefore stepped out and their place was taken by a man no less able, but trained in the peculiar methods of bureaucratic governmental administration.

A few months ago the head of the drainage department of this government lost his position and is disgraced because of a technical violation of the statutes. Upon the face of it he was dismissed for rank dishonesty, as one newspaper-informed citizen told me the other day, but as a matter of fact he should not have been dismissed, because the country got the full benefit of all money spent and it was only his method of getting around an absurd regulation which led to his dismissal. Had he not obtained money temporarily his organization would have lost the services permanently of the best men in it. No one lost one cent and the government was the gainer, but the lynx-eyed investigator and his attorneys decided otherwise, although the head of the department acted under the advice of the legal advisor to his department.

The subject of river pollution became a live one in Great Britain in 1857, and the over enthusiastic men employed on the various commissions set such high standards of purification that millions of dollars were needlessly spent. Until the policy was adopted of permitting separate districts to handle their own troubles under the guidance of specialists, no real gain was made. The interference of the state in engineering matters was too great and the men employed were not always first class men, for the pay was not adequate. It was the usual trouble with a too large organization, that of having the organization controlled by men with small ideas. Dr. Dunbar, in his "Principles of Sewage Treatment," in referring to the separate boards finally found best in Great Britain, says "such an authority should be free from bureaucratic influence, able to follow the technical and scientific advances made in the subject, and free to make its decisions, after judging each individual case on its merits."

In Ohio, where there is a board of health with great powers, the city of Marietta was one of the first cities to use sulphate of iron in a filtration plant instead of the alum that was commonly used. There were certain decided advantages for the city in using the iron and no disadvantages, but the state board officials refused to permit the use of the sulphate of iron because it contained a small per cent of copper. The city used the material nevertheless and it took a lawsuit to settle the matter. It was found that the natural water in the river contained more copper than the filtered water, even after the small amount in the coagulant had entered it. It was found that when alum was used there appeared to be more copper

in the filtered water than when the sulphate of iron was used. In no case was there enough to cause any danger and the well known properties of copper sulphate as a germicide would apparently have made it a valuable addition instead of a danger. This action on the part of the state board was nothing more than "fussiness," a characteristic of so many bureaucrats and men of small ideas when armed with authority.

The state has a perfect right to safeguard the health of the people. We all expect it, no matter how much it may interfere with our own private interests. There does exist, however, a real danger of much harm being done by undue interference. Take, for example, the case of where an examination may be held for engineer of a state board of health, at a salary of $1,500 per annum, to pass on all plans prepared for the purification of water and sewage. Imagine the calibre of the man secured as a result. A large city has plans prepared by men eminent in their profession, whose compensation for one week is perhaps greater than the annual compensation of the man whose duty it is to examine their plans and give his approval before the works may be constructed. He may disapprove of many advanced ideas expressed in the plans and specifications, and it becomes the disagreeable duty of the eminent specialist to unbend from his high dignity and patiently act the part of a kindergarten teacher until he has brought the state's adviser up to date. Sometimes he runs across a man of such a temperament that he will not recede from his first position. These things happen very often, much oftener than those who do not come in contact with them would imagine. There is a remedy. It is to do as has been done in Great Britain; set a minimum of requirements, then let the localities affected work out their own salvation and have the state then submit the plans to the best specialists obtainable; the interested parties footing all the bills. This will not discourage initiative nor unduly exalt the small minded man.

Much interest has been aroused lately by what was thought to be an offer of wholesale free bridge designing and superintendence of construction by the Federal Government. A storm was raised over the matter and when proper explanations were made it was found that the poor education of the government engineers in writing English was responsible for the trouble. The pamphlets did not mean what they said exactly. Enough was meant, however, to constitute a real menace and to largely do away with the idea of local organizations to handle local problems.

The government bureau of highways should confine its activities entirely to work of an educative nature, as in the past, and each state should organize a department of engineering to handle highway and bridge construction within the state. I believe that the cities and counties should be compelled to obtain plans and specifications for bridges from independent designers and call for bids on these plans, instead of compelling bidders to furnish their own

plans, although not forbidding them to do so if they wish. There should be a central state department where all these plans may be carefully checked, merely to ascertain that they are safe and that the public will not be in any danger in case the plans are adopted for the intended structure.

What the end will be we all know. Some day all work on the roads, bridges, rivers, etc., will be done by engineers in the employ of the government, state or national. There may be large government schools established in which men will be trained for government work, or the present system of each man paying for his own education may be retained and the government engineers secured through severe examinations. Whatever method may be adopted, we cannot question the fact that present tendencies point to a larger measure of governmental control in the future than we have at present. A small paid job with the government and a retiring pension will become the dream of many here as it is the dream of all engineers now in France.

During the transition period there will be considerable opposition, and societies such as the Western Society of Engineers should constantly guard the best interests of the members by scrutinizing closely all proposed legislation, to the end that too close regulation of private work will not be attempted and that initiative and ingenuity on the part of engineers now living will not be crushed. Just as local option seems to be the best solution for the much discussed liquor regulation problem, so it would seem that the largest possible measure of local self government consistent with public interests should be given the people. The tendency of men now in the permanent employ of the state to enlarge their departments and increase their own importance at the expense of the others not fortunate enough to be attached to a permanent pay roll, should be resisted in a sensible manner.

Perhaps this is after all a wandering talk and leads nowhere. Personally I would like to see the relation of the state to engineering, during my life, limited to the following:

1. The state board of health to provide minimum requirements for the purification of water and sewage and let each community select its own experts to prepare plans. These plans to be approved, not by a low paid man, but by eminent experts who shall be paid by the community affected and not by the state.

2. The state engineer to fix regulations for the design and construction of all structures used by the public or intended for the public benefit; this to cover buildings, bridges and dams. The communities or corporations erecting these structures to be allowed to select their own designers and engineers and the plans to be subject to the approval of the state engineer, but his decision to be submitted to other experts in case the designers for the owners object to his ruling.

3. The creation ultimately of a state engineering department

which will have the care of all roads and bridges, even making all the designs and superintending construction and repairs, but limited to this work exclusively, all expense to be borne locally.

Paul Evans Green, M. W. S. E.: I agree with almost everything everybody has said, except possibly one statement made by Mr. Sherman, that there should be no line drawn between the various communities or units that should receive the benefit of state supervision. I think that is a mistake. I believe that the line should be drawn, for instance, between government organizations that are capable of handling considerable work and organizations that are not capable. In any incorporated community the tendency, I believe, is to elect men to office who are men of some force, men who are leaders in their community. In the smaller units, such as townships and unincorporated sections, there is not the incentive to elect men of capacity to attend to the work that must be done, such as highway supervision and bridge building in these country districts. While the law may not at present permit any discrimination, it seems to me that it would only be equitable to practicing engineers, who are also tax payers, that there should be discrimination. In my own experience, covering some country bridge work, at the end of a certain period I came to fully believe in state supervision of country bridge work and of highway work. I found, for instance, that the contractor was invariably a man of very much greater force than the local highway officials, that politics played a large part in the awarding of the contract, and that the consulting engineer is ignored. I think, too, that under these conditions the contracts are often awarded by highway commissioners who are not competent to pass in any way upon the work and who do not know the difference between engineer and contractor. In the case of small municipalities I do not think as a rule that this would apply. The mayor and the council are generally men of some force. These small towns and communities, at least in Illinois, are almost invariably wealthy, and I believe that it is just as much an anomaly to have the state engineering officials prepare plans and supervise the work, other than in a general advisory capacity, as it would be to have the attorney-general of the state try the local legal cases.

J. G. Gabelman, M. W. S. E.: The thought occurred to me that the state highway engineer might be of great aid in an advisory capacity in passing on special assessments. I do not mean that he should make up estimates, but after the city engineer in a small town has made up an estimate for local improvements, it might be well to have the state highway engineer pass on it as to methods of procedure, etc. Often the wording in an engineer's estimate may be the cause of a much needed improvement being dismissed in court. It happens quite frequently that a petition is dismissed for want of a proper understanding of the special assessment laws on the part of city engineers. Probably the engineer is thoroughly competent, but in making his estimate he will get in

some wording that will not suit the judge or the lawyers and the petition is dismissed and the improvements delayed. After the engineer has made his estimate, if he could submit it to the state highway engineer and get advice as to whether he had followed the assessment laws, a great deal of this could be avoided. I particularly mention this because I have heard of three or four cases lately where petitions for special assessments have been dismissed in court on account of matters of that kind.

E. R. Shnable, M. W. S. E. (by letter): I would suggest the following as of great assistance, primarily, in establishing a better "Relation of the State to the Practice of Engineering." That, whenever possible, all engineering societies and civil engineers promote the nomination and election of one or more of their membership to the State Legislature.

The framing of laws pertaining to engineering questions and policies will then have the assistance of trained and practical men, and the passage of unwise and imperfect laws will certainly be checked.

Furthermore, the engineering profession will then have some one, in legislative authority, with whom to consult and advise.

DEPRECIATION AND REPLACEMENT OF GROWING TELEPHONE PLANTS

BURKE SMITH.

Presented Before a Joint Meeting of the Electrical Section W. S. E., and Chicago Section A. I. E. E., April 22, 1912.

Electrical plants of all kinds now in operation in the United States have, almost without exception, grown very rapidly. In fact, growth has been so rapid and the period of development so short that the evolution and standardization of apparatus and material by manufacturers has hardly kept pace with the demands of the operating companies.

General and local conditions of business affect the growth of particular companies. Thus in times of general financial stringency new construction work is reduced to a minimum, while in periods of prosperity and favorable conditions for development the reverse is true. However, a study of the growth of existing companies will show, in general, three distinct periods of development, as follows:

(1) A period embracing the beginning years of business during which the company developed into a "going" concern, and during which the growth was not especially rapid.

(2) A period of comparatively rapid growth and development, through which many companies are still passing.

(3) A period of saturation or comparatively slow growth and more stable condition, corresponding more or less to the rate of growth of population and the general development of the community in which the company operates.

Telephone companies today are mostly in the second period of development, the growth in the telephone industry as a whole having been especially marked since the early nineties. According to statistics of the American Telephone and Telegraph Company the increase in Bell telephone stations (not including so-called "connected" stations) at five-year intervals, from 1895 to 1910, has been as follows: Starting with 281,695 stations at the end of 1895, the growth was 185% in the period from 1895 to 1900; 180% in the period from 1900 to 1905, and 80% in the period from 1905 to 1910, while there was about 11% growth in 1911. The investment in plant has necessarily kept pace with the station growth.

That the present telephone development is only a small part of what may be expected in the future, is shown by the figures in the case of a few cities in which development has been carried out to a much greater extent than the average for the country at large. Thus, while the average number of Bell telephones

per 100 inhabitants in 108 cities of over 50,000 population in the United States was 8.4 for January 1, 1911, the corresponding figures were 18.7 for Spokane, 17.9 for San Francisco, 17.7 for Omaha, 16.4 for Dallas, and 16 for Des Moines. These figures apply merely to the development in the Associated Bell Companies and do not include Indepedent telephones.

In none of the above-mentioned cities is it safe to say that saturation is yet in sight, as years immediately preceding show a steady increase in percentage of development. These cities show the highest development of any above 50,000 population in the United States. However, the same rapid rate of increase is found in almost all other cities.

The general subject of depreciation has been fairly well covered in commission reports and court decisions, and in recent published articles by engineers. It is believed, however, that the effect of age and rate of growth on the depreciation problem is not as well understood at present as it should be. Because of its comparatively rapid and recent growth, the average telephone plant in particular has to deal with a depreciation problem which is essentially different from that of a fixed and well established plant. In the present paper an effort will be made to point out some effects of age, growth, and other phases of depreciation which apply more especially to telephone properties. Much of what follows will apply not only to the telephone but to other utilities operating today.

REPLACEMENTS (RENEWALS).

Physical plant begins to deteriorate, in general, immediately after it is put into service, and in time requires replacement. In some cases physical plant has a certain salvage value or serviceableness after removal, either as junk, in a disintegrated condition, or as serviceable plant to be used over again. When the salvage value is subtracted from the original cost in place, we have the wearing value.

Various causes combine to bring about the replacement of physical plant. Brief mention of some of these causes follows:

(1) Normal wear and tear. In order to keep the plant in good working condition repairs, changes, and replacements of small parts, due to normal wear and tear, are necessary, and are usually included under the term *current maintenance*.

(2) Decrepitude, or gradual deterioration, due to natural and usual causes.

(3) Obsolescence, or depreciation due to improvements or changes in the state of the art. Obsolescence may be due to invention or other demands which call for abandonment of plant which has not lived to the end of its usefulness. In the telephone field, obsolescence has been a very large factor in expenditures for replacements in the past, and continues to

be a large factor at the present time, owing to the rapid development of new and revolutionary inventions and methods, and lack of standardization.

(4) Inadequacy, or inability to meet the increased demands of service in an economical or convenient manner. Inadequacy may be due to more rapid growth than could be foreseen. Public utility companies are required, by the police power of regulating bodies, to provide adequate means for giving service, and in the case of a telephone company, in order to have the proper facilities to take care of future demands and build its plant economically, the direction and rate of growth of business in the territory which it covers must be anticipated many years in advance. Any substantial deviation of actual growth from anticipated growth, either in the general number of stations or in the number of stations in a particular locality, will mean either idle plant or inadequate plant. The telephone business is unique among public utilities, in that there is little overload capacity. The plant must be built to take care of all emergencies.

(5) Municipal requirements and legislation. With telephone and other companies occupying public property, replacements due to such causes are often large in amount and may come when least expected.

(6) Damage by extraordinary occurrences, such as accidents or the forces of nature.

(7) Deferred maintenance, or depreciation due to neglect. Under this heading may be included neglect resulting from strikes.

(8) Combinations of competing companies, which result in duplication and consequent rearrangement of plant. Such rearrangement of plant may properly be regarded as supercession, rather than replacement. However, it has an effect on the average length of service of the plant as a whole, and consequently may be mentioned here.

LIFE.

The term *life* as ordinarily applied to physical property has two meanings, which should be carefully distinguished from each other.

(a) The *natural* life, or length of time which elapses from date of installation to date of replacement, the replacement being made necessary through physical decay or decrepitude or normal wear and tear.

(b) The *average* life, or length of service from date of installation to date of replacement, as determined from past experience and observations on plant installed and in actual service. It may perhaps be defined more accurately as the most probable length of service, taking into consideration some or all of the above causes as well as local conditions which may bring about

replacements. The available life tables of various kinds of electrical apparatus and material made up by different engineers and commissions, differ widely. This especially is true of life tables of telephone apparatus and material, and is due in part to a use of the term life to mean in some cases the natural life, and in other cases the life without regard to the effects of obsolescence or inadequacy. Other causes are lack of standardization in manufacture of apparatus, difference in amount and character of maintenance among different companies, and, in particular, lack of sufficient data in regard to length of service of apparatus and material which has been installed in the past.

When considering the question of replacement, the term life should mean the average life, taking into account all of the factors which may make replacements necessary. Some of these factors have too often been omitted in dealing with the subject of depreciation. From the meaning of the term average life, it is evidently impossible to give more than an approximate figure for the average life of the various classes of plant. Furthermore, replacements of small units or small parts will begin immediately after installation. For example, some telephone subscribers' sets may have to be replaced soon after being installed, due to damage by fire or accident, or due to necessary changes in the electrical circuit. The parts of a switchboard, such as plugs, jacks, cords, relays, wiring, etc., must be replaced in small amounts from the time the board is installed to the time it has reached the end of its usefulness. A sleet storm may make necessary the replacement of wires and poles which have been erected but a short time; electrolysis may destroy a cable after it has been in service but a few years. Thus, renewals due to external or natural causes begin immediately after apparatus is installed.

On the other hand, some kinds of plant will remain in service for a longer time than the average. The tendency of this distribution of renewals over a number of years is to smooth out the curve of renewals, and to make the estimation of future renewals in time and amount more difficult. To illustrate, in Fig. 1, the area *A* represents the cost of apparatus installed during a given year. Then if the average life has been determined as, say, approximately 10 years, the areas *B* and *C* will represent, in theory, the first and second renewals which should take place. In actual practice, renewals will usually begin previous to 10 years, and some of the apparatus will remain in service for some time after the 10-year perod. Suppose, for example, that the curve *D* represents the law which the replacements actually follow, the area under the curve *D* being equal to the original area *A*. Then, assuming that the same law holds for the replacement of the plant which takes the place of that first installed, the second replacement will be represented by the area under curve *E*. But since

some apparatus will have been replaced three or four times, and all apparatus will be replaced twice, the curve *E* will have a tendency to spread out over a greater number of years and enclose more area than the curve *D*. In other words, in actual practice the amount of renewals necessary in a given period may be substantially greater than that which is indicated by assuming that the entire replacement takes place at the end of the average life.

COMPOSITE LIFE OF PHYSICAL PLANT.

In order to treat a composite physical plant as one unit, without regard to the separate units of plant of which it is made up, it is necessary to consider its composite life. This may be defined as a period of years such that the total deterioration of the plant during this period will amount to the wearing value of the plant as a whole. The deterioration of plant in this sense includes both replacements and depreciation of existing plant. The composite life has no physical meaning in the sense that

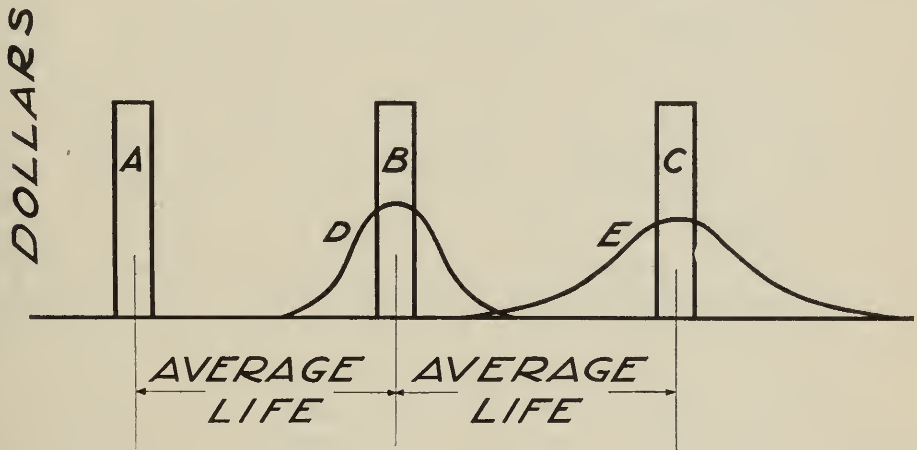


Fig. 1.

the plant will come to the end of its life at the end of the period, and that we would consequently have an entirely new plant immediately following this period. It is, however, a convenient way of expressing the effect of depreciation occurring in the plant as a whole.

The estimated amount of deterioration during a period should be the same whether obtained by taking into account each separate class of plant, together with its average life, or whether obtained by taking into account the plant as a whole. The actual replacements, however, which will come due at any given time, assuming that the average lives of the different classes of plants are known with some degree of accuracy, can be more closely estimated by using average-life figures for each class of plant, rather than using the composite life and treating the plant as a whole.

October, 1912

A comparison of the estimated composite lives of a number of different public utilities shows that telephone plants are much shorter lived than plants of other utilites, the average figures as reported by the Wisconsin Commission being something like 11¼ years for telephone plants, 17½ years for electric lighting properties, 18 years for electric railways, 30 years for a gas plant, and 60 years for a water plant.

Moreover, the composite life of a telephone plant will vary during different periods of its growth and development. Take, for example, an established telephone company in a large city, which has been in existence for, say, 20 years or more.

During the first period of growth, when business was in process of development and the art of telephony was in a very crude stage, much of the plant was of temporary character. Switchboards were soon rendered obsolete and the outside plant was entirely aerial, and especially liable to damage by storms or accident.

A second period of growth includes the present. During this period, the art of telephony has advanced to its present highly developed state, overhead type of construction has in a large measure given way to the underground, and growth has taken place very rapidly. Inadequacy and obsolescence have played a very prominent part in the changes which have taken place, as already mentioned. Additions to plant in different years have been necessarily made up of different kinds of plants. Thus, one year, central office equipment may be the principal item; another year, conduit and cable; another year, buildings, etc.

A third period of growth will begin when saturation is reached. This period is no doubt in the remote future, but if we may speculate in regard to it we may say that growth during this period will depend largely upon the growth of populaton.

The above considerations lead one to believe that the composite life of a telephone plant in general should increase with growth and development. But such an increase is by no means certain, on account of the number of factors involved. For example, at the present time, modern transmission standards make necessary the use of improved types of cable to take the place of old types. The semi-automatic switchboard may make advisable the replacement, in the near future, of manual boards. Large changes in sub-station equipment may be necessary at times in order to introduce improved service. Legislation and municipal requirements may be the cause of much reconstruction. The increasing number of high tension power circuits built in proximity to telephone circuits necessitates changes in location of lines or in protective measures. Other factors, such as wireless telephony and the telephone repeater. have possibilities. It is

impossible to say what the future has in store for telephony, but where there is progress there is change and obsolescence.

PROVISION FOR REPLACEMENT OF PLANT.

If a company is to continue in business in the future, and a public utility company has no choice in this respect, the various replacements already outlined constitute a source of expense which is as real as any which a company has to face. If the original investment in plant is to remain intact, the cost of that portion of replacements which equals the original cost of the plant displaced cannot be capitalized, but should be paid out of earnings. An exception is sometimes made in the case of replacements due to obsolescence or inadequacy. It is doubtful if much of the growth and development in electrical properties in the past would have taken place as rapidly, or as extensively, if it had been necessary to pay for all replacements due to obsolescence out of earnings, and these earnings had been limited in amount by rate regulation. Replacements will often be compulsory. A company must sometimes install improved apparatus and give improved service because it is demanded by the public. For example, although it might be expensive for a telephone company to change from local battery to common battery operation, or from code ringing to selective ringing, the company has often no choice in the matter when the subscribers demand the change. Again, an unexpected order from a legislative body may make necessary the taking down of all poles in a certain section of territory, even if some of the poles had been in service only a few months. In large cities, conduit and cable plant must often be reconstructed, owing to municipal requirements.

Under public regulation and control of corporations, the rates should be so adjusted as to permit of all replacements—whether from obsolescence, inadequacy or other causes—being paid out of earnings.* It is implied in this, of course, that the management is efficient and that replacements due to obsolescence and inadequacy are necessary, either from an engineering and economical standpoint or on account of legislation or public demand.

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*In regard to this point, one public utility commission has gone on record as follows: "Undoubtedly such losses as wear and tear, abrasion, corrosion, deterioration due to time and the elements, and other items of this character, are a part of the cost of producing the services rendered and should therefore be borne by the consumers. This would also seem to be true of obsolescence due to progress in the art, especially when the cost resulting therefrom is not offset by increased efficiency evidenced either by increases in the earnings or reductions in the operating expenses. Inadequacy due to the growth of the business, particularly when it results in net losses to the utility, would also seem to come in this class."

Wisconsin Railroad Commission Reports, Vol. 4, p. 599, State Journal Ptg. Co. v. Madison Gas & Electric Co.

There are three methods of providing for replacements which may be mentioned:

METHOD 1.

Capitalize replacements. This method, if used to any great extent, is indefensible. This has been pointed out many times. It may be remarked in passing, however, that for a rapidly growing plant it may not be as disastrous as for a fixed plant, since the inflation of the plant account in the former case will be relatively smaller than in the latter case.

METHOD 2.

This method consists in treating all replacements of plant simply as current maintenance ,regardless of the causes to which they may be due. Only that portion of the cost of replacements which equals the original cost of plant displaced is charged to operating expenses, the remaining portion being considered as an increase to the total plant. Under this method no provision is made in advance for expenditures for replacements.

This method is the usual one with steam railroads and some large street railway companies. It does not, in the writer's opinion, apply to telephone plants without some modifications, because it assumes:

1st. A plant having numerous physical elements, each element forming but a small part of the whole plant. Few telephone companies in existence at the present time have plants large enough to show these characteristics. Replacement costs of switchboards, buildings, conduit runs and pole lines, which must all be considered in this connection as single units of plant, are examples of items which are greater than should be charged to operating expenses at one time.

2nd. A plant in which replacements due to sudden and unexpected causes are comparatively small in amount. Plants which are subject to municipal requirements, inadequacy, obsolescence, or damage by storm or accident have to face replacements which may be excessive in amount and may come when least expected.

3rd. A plant which has had a fairly uniform growth. The effect of a changing and rapid rate of growth is to cause corresponding changes in the rate at which plant must be replaced.

4th. Earnings available each year in sufficient amount to allow an adequate sum for replacements. In every business there are prosperous years and dull years. As a matter of insurance against lack of funds for renewals in dull years, some provision should be made in advance instead of depending upon the earnings which come in from year to year.

METHOD 3.

This method consists in setting up a depreciation reserve fund, or "Replacement Reserve," paid in annual installments, and such that the total of all contributions, with or without interest, as the case may be, will amount to the "wearing value" of the original property at the end of its life.

In some cases a distinction is made between a reserve fund for special insurance against sudden and infrequent replacements and a reserve fund to take care of continuous depreciation. It would seem that any plant which is exposed to the elements, or which is liable to sudden and unexpected need for reconstruction, should be protected by a special insurance fund. Also the element of chance entering into such matters would call for an ample margin of safety.

As applied to telephone properties, it is believed that the building up of proper reserve funds is the only safe procedure to follow. Current maintenance cannot be sharply distinguished from actual replacements in a plant made up of a very large number of small units. Some of the apparatus which goes to make up a telephone plant is of this kind and replacements of such small parts may be charged to current maintenance. But in order to adequately provide for sudden and unpredicted replacements of large amounts of plant made necessary by obsolescence, inadequacy, storms, accidents, and public requirements to which telephone plant is largely subject, some special insurance in the way of a reserve fund must be provided. Consideration of the points mentioned under Method 2 would seem to make the accumulation of a replacement reserve fund necessary to any company desiring to conduct its business on a sound financial basis.

DETERMINATION OF PROPER AMOUNT TO BE PUT INTO A RESERVE FUND.

It is evident from what precedes that the accurate determination of the amount of necessary renewals of telephone plant for any length of time in advance is impossible. Indeed, it is believed that an exact forecast of the amount of replacements for even one year in advance is impossible for the average telephone plant of any considerable size. Depreciation or deterioration due to such causes as obsolescence, inadequacy, changes in competitive conditions, legislation, storms and accidents cannot be predicted with precision. For this reason the exact amount of money which should be put into a reserve fund each year, to provide for future replacements, cannot be easily determined.

One method of estimating this amount is based on an estimate of the composite life of the plant. According to this method, if the composite life of the plant is estimated to be n years, then $1/n$ of the total wearing value of the plant should be put

into the reserve each year, assuming that the fund will earn no interest. If the fund earns a given rate of interest, the amount to be put into the reserve each year will be less. Assuming that the fund will earn no interest, it may be shown that this method is equivalent to taking the life of each separate unit of plant and calculating the total sum which should be put into the reserve to properly care for all the separate units.

The determination of the composite life of a telephone plant with exactness is a difficult matter. Plant that is installed new from year to year may have to be entirely replaced long before the time estimated as the end of its life, or, on the other hand, it may last longer than is estimated. For this reason this method cannot be regarded as giving results which are dependable in every case. It can be used, however ,to give reasonable limits for the amount which should be accumulated, a close study of the conditions involved, and the experience of the past supplementing the estimate thus obtained. Some margin of safety should also be allowed on account of the uncertainty.

Most problems today which have to do with the building up of reserve funds have to deal with old, well-established plants which have been in business for many years, rather than with new plants just starting in business. The importance of a proper reserve fund in the case of many such companies was not recognized in the past, and an adequate reserve does not exist at present. For such companies there are at the present time two distinct problems: *First,* the determination of the proper amount which should be in the reserve at the present time, in order to properly take care of replacement of existing plant when it comes to the end of its life. *Second,* the determination of the proper amount which should be put into the reserve to take care of the replacement of new additions to plant from year to year.

The second problem is perhaps more capable of solution than the first, since in the case of yearly additions to plant we are dealing with entirely new plant with the experience of the past to guide us, and the accounting system may be arranged to enable us to revise our estimate of depreciation from time to time. Even then, the best we can do is to use our judgment and draw on past experience as much as possible in making a reasonable forecast of future life.

It is not the intention of the writer to discuss these problems here, other than to mention some facts which have a direct bearing on their solution. In regard to the first problem, it may be proposed that we should fall back on an appraisal. But one should not overlook the fact that however well we may be able to estimate the present condition or depreciated value of existing plant, and however well we may be able to estimate future life based on present physical condition, no one is able to estimate the effect which obsolescence, inadequacy, public requirements

and the forces of nature will have upon the future life of the existing plant. Judging from past experience in the telephone field, these factors will have a much greater effect than normal wear and tear or decrepitude.

It has been claimed by some that in the case of an old established plant which has been in service long enough to eliminate the effects of the first period of growth and development of business, and where the plant has reached its normal operating state, the amount of which should be put into the reserve may be estimated approximately by averaging the cost of replacements for a period of years in the past. That is, if a company operating today finds that annual renewals aside from current maintenance have averaged, say, 3% of the total investment in the last five years, then 3% should be enough, on the average, to care for renewals in the future. On account of the rapidity of growth of every telephone company of any considerable size in the United States, and other reasons already mentioned, it is believed that in hardly a single instance will the future replacements be reflected in the present and past reconstruction accounts in this way. Estimates of the composite life of telephone plants in large cities, obtained from different sources, vary from 11 years to 14 years. Assuming a salvage value on the plant as a whole of, say, 10%, this would mean 8.2% to 6.4% of the total investment as the proper amount on a straight line basis to put into the reserve each year to provide for future replacements. It does not follow, however, that renewals in a properly maintained telephone plant should average as high as this at the present time. During the first few years of existence of a new and growing plant, the cost of renewals will ordinarily be small. This is more especially true of long-lived plants. A waterworks company, for example, might not require more than a few minor renewals to its water mains for 15 or 20 years after date of installation. Many telephone companies operating today are not old enough to eliminate the effects of the beginning years of business. Furthermore, a rapidly growing plant will always be in a condition of more than 50% new, due to the annual additions of new plant, part of which is growth and part is installed to take the place of depreciated plant. This will also tend to make renewals small until after the rate of growth becomes comparatively slow and uniform.

If adequate funds are laid aside for future replacement of plant under the sinking-fund method, a considerable amount of money may be accumulated in the beginning years of business before renewals begin to assume large proportions. And if the plant is a rapidly-growing one, this excess reserve fund may continue to increase, since renewals form a smaller percentage of the investment than is the case in a fixed plant. A large

reserve fund should not influence those having in charge the responsibility of providing for the future to cut down the rate at which the reserve is being accumulated, provided this rate has been determined by a careful forecast of the future life. If it is certain that such funds will be needed at some future time, they should be accumulated in advance.

A lack of appreciation of the above facts, both by the public and by public utilities, no doubt has had much to do with adequate reserve funds not being provided in the past.

EXAMPLE BASED ON AN ACTUAL WORKING PLANT.

In order to bring out more clearly the small amount of replacements which may be expected in a rapidly growing plant, as compared with a fixed plant, the following example, based on investment figures from an actual working telephone company, is submitted. The plant which is here considered is in operation today in one of the larger cities of the United States. It is believed that in age and rate of growth it is representative of a large number of telephone plants now in operation.

This company is some 25 years of age. Previous to 1890 growth was slow and the investment in plant was comparatively small. The investment previous to this year has therefore not been taken into account.

Soon after 1890 the plant began to grow rapidly and a fairly steady rate of growth has been maintained up to the present time. The average investment in depreciable plant for each year for the period of 1890 to 1910 is shown in Fig. 2, the investment increasing from $50,000 to $4,800,000 during the period. An inspection of this curve shows that there was a particularly rapid growth between 1898 and 1902 and also between 1905 and 1907. The general trend of growth for the period, however, is not excessive for a telephone plant in a large city.

In order to calculate the amount of theoretical replacements, the investment may be conveniently divided into eight different classes, each class having a certain average life. The division of the plant in this way, for 1910, together with the assumed average lives, is shown in the following table:

	Percentage of Total Plant, 1910	Assumed Average Life (Yrs.)
Central office equipment	13.3	8.5
Underground cable	15.9	19
Underground conduit	17.1	35
Aerial cable	4.3	12
Aerial wire	10.3	11
Poles	13.0	10
Subscribers stations and private branch exchange terminals	18.4	9
Buildings	7.7	24

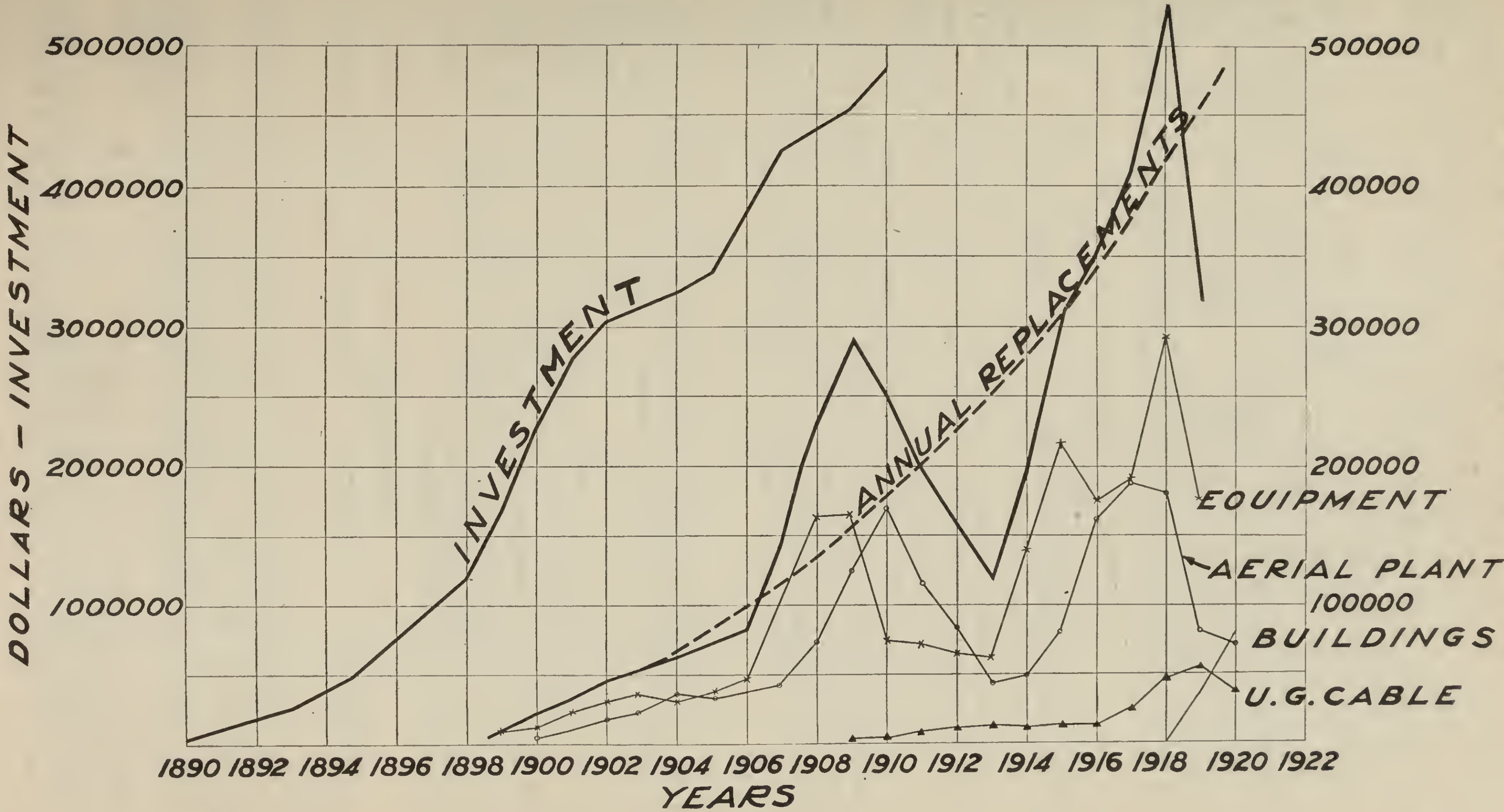
DOLLARS - INVESTMENT
5000000
4000000
3000000
2000000
1000000
INVESTMENT
ANNUAL REPLACEMENTS
EQUIPMENT
AERIAL PLANT
BUILDINGS
U.G. CABLE
DOLLARS-REPLACEMENTS
500000
400000
300000
200000
100000
1890 1892 1894 1896 1898 1900 1902 1904 1906 1908 1910 1912 1914 1916 1918 1920 1922
YEARS

Fig. 2.

It was assumed, for the sake of simplicity, that the different units of plant are replaced exactly at the end of their average lives—that is, that no replacements will take place sooner than or later than the average.

In Fig. 2 is shown the calculated annual replacements of wearing values of plant, the scale being ten times that of the investment curve. Replacements of subscribers' stations and central office equipment are combined into one curve, and aerial wire and aerial cable into another. The combined annual replacements of all classes of plant are shown as a heavy solid line, while the heavy dotted line shows the trend of this curve. It will be noted that the principal items which go to make up this curve are equipment and aerial plant. Underground cable and buildings havé very little effect up to 1920, while replacements of underground conduit do not appear at all. These curves are theoretical and it is not claimed that they represent accurately the annual amount of renewals which should be expected. The assumed values for average lives and salvage may not be the most reasonable ones to use in this particular case. But it is believed that these curves do show the *trend* of the replacements for an investment curve of the general form here assumed. Complete figures from the company's books were not available to enable a comparison to be made between the calculated values and the actual amount which the company spent on renewals.

An inspection of the curves, taking the trend curve as giving the most reasonable results, shows that in 1910, after 20 years of operation, the calculated annual replacements form only 3.7% of the total investment. This rate is much lower than would be the case if we were dealing with an old and fixed plant, as can be shown by calculating the composite life. It should be noted, however, that replacements, according to the curve are steadily increasing, being about 1% of the investment in 1901, 2% in 1904, and 3% in 1907. It is logical to suppose that this increase will continue.

CONCLUSION.

In conclusion, it is desired to emphasize the three following points:

1st. In a telephone plant which is growing rapidly, annual replacements should be small as compared with replacements in a fixed plant or one which has a slow rate of growth.

2nd. In an average growing telephone plant today, replacements should form a steadily increasing percentage of the total investment, and should in time approximate the amount which would be expected in a fixed plant.

3rd. The fact that replacements in a growing plant form, at the present time, a comparatively small percentage of the total

investment is not a valid reason for lessening the amount of reserve fund which a study of the life of the plant would show is necessary for future replacements.

These three principles apply not only to a telephone plant but to any kind of a plant which is made up of depreciable property. In regard to the second, it is conceivable that the growth of a plant may be so rapid that replacements, when expressed as a percentage of total investment, may remain constant or may even decrease for a time. In fact, the necessary conditions for such a result may easily be expressed in mathematical form. However, a more stable condition must be reached in time, and replacement percentages will then show an upward trend.

Discussion.

P. B. Woodworth, M. W. S. E. (Chairman): I am sure we have listened with profit to a paper which is a very good analysis of the situation.

I am going to ask Mr. Hyatt if he has not some discussion to offer.

A. P. Hyatt: I am especially interested in the central office equipment, and I think it might be of interest if Mr. Smith could tell us something more of the average life of switchboards in, say, a large city like Chicago. They have changed very rapidly here in the last ten years. Possibly he has some data here that will tell us how short-lived they are.

Mr. Smith: I assumed eight and one-half years as an average, but studies of replacements of switchboards which have been made in the past show a shorter life than that. Of course, it is hard to predict what will happen in the future, but it is possible that the semi-automatic board may displace our present boards in time. For this reason it is not safe to assume a longer life in the future than is justified by experience in the past.

Prof. Woodworth: Will the semi-automatic switchboard absolutely displace the present switchboard? In other words, will it be necessary to put in a new switchboard, or can the present one be reconstructed so as to be partially available?

Mr. Smith: I cannot say as to that. I would rather not discuss that question.

S. R. Edwards: Some information about reserve funds which are set aside to take care of sleet storms, floods, and other things of that nature would be of interest. About a month ago a sleet storm did a great deal of damage in the central part of the state. What provision would be made to take care of storms of that nature?

Mr. Smith: As I mentioned in the paper, a telephone company should provide a special insurance fund to insure against damage from floods, sleet storms, and other extraordinary occur-

rences. This is more necessary in the case of a telephone company than with some other public-utility companies. As to the amount of such provision which it is customary for a telephone company to make, I am not in a position to discuss that.

Mr. Edwards: How would that fund be set aside, what percentage each year, or should it be a growing percentage each year that the life of the plant increases?

Mr. Smith: I would not want to answer Mr. Edwards' question offhand. All I want to bring out is the fact that such funds should be set aside.

R. V. Achatz: I would like to ask as to the policy in the matter of replacements. It is a fact that telephone companies—the size of the Chicago Telephone Company, for instance—if they make any radical change in equipment (say central office equipment, since that is changing most rapidly), will in all probability start making the change in the most antiquated equipment they have. They proceed with the change, and perhaps a number of years elapse before the change is completed throughout the entire plant. During that time the newer equipment of the obsolete type is getting on toward the end of its wearing life before it is replaced. Is this policy going to have any effect in the future upon the amount of replacement due to inadequacy and obsolescence?

Mr. Smith: I am not sure that I understand your inquiry, but I suppose you desire to know whether all replacements due to obsolescence are made in time to keep the plant which is replaced from becoming obsolete.

Mr. Achatz: As a matter of fact, does not the tendency to replace the plant by degrees keep down the amount of replacements necessary on account of obsolescence, and make it more dependent upon the natural life of the plant?

Mr. Smith: Of course, replacements due to obsolescence do not clear out all of the obsolete material from the plant, because usually, if the management is efficient, the company would not replace all of the obsolete material so long as they could use it. Obsolescence does not bring about as complete a change as one might expect, but a study of the facts in the past would show that obsolescence has been a very large factor in reconstruction accounts. As far as the future is concerned, I think we ought to take the position that we can best predict the future by what has happened in the past.

Mr. Achatz: What I desire to know is whether obsolescence, outside of the municipal regulations, will probably be a smaller item in the future.

Mr. Smith: I think that is more or less speculation, but the safest course to follow is to rely on past experience.

Prof. Woodworth: In other words, I take it, the idea is

that just as soon as plants in general begin to reach standard types, then the change takes place much less rapidly. It is only a question of development to a standard type.

I believe the gentleman who is probably best informed on that particular subject is one who has been through the building of a type from its elementary stage to its final standard type stage. I will ask Mr. G. T. Seely if he will not tell us something of the experience in the traction line on that question of obsolescence?

G. T. Seely, M. W. S. E.: Obsolescence on elevated lines differs in the various properties. Some of the elevated lines in Chicago were built before the age of electrification. Two of the lines were built to use steam locomotives, and those locomotives were in use only a few years. By that time the electric railway art developed to such an extent that it seemed necessary to electrify the lines, making the old steam equipment obsolete. As another example, the South Side Elevated Railroad, when the line was built in 1892, lighted all the cars by Pintsch gas, and an expensive outfit was installed to light all the stations with Pintsch gas. Afterwards, electric lighting was adopted, and the line was wired for electric lights, under the A. C. system, with transformers at each station. A generating plant was built, because the road was still operated by steam. A little later the line was electrified, and the cars were supplied with electricity, which meant that the Pintsch gas outfit for the cars was obsolete. The same system of lighting was adopted in the stations, changing from the A. C. system to the series D. C. system. Inside of five or six years there were two complete changes in station lighting, two installations becoming obsolete. All the equipment for the propulsion of trains by steam became obsolete, and in the case of the South Side Elevated Railroad there is a very large item of obsolescence. The Northwestern Elevated Railroad was built in about 1898 or 1899, and commenced operation in 1901. On this road, which has a value of over $30,000,000, one cannot find $50,000 of obsolescence. Practically everything is being used now that was in use when the road started. This shows that obsolescence, as far as an elevated road is concerned, depends upon the time when the road was built. The property of an elevated road is subject to less obsolescence, perhaps, than any other line of business. Nearly everything has a long life. The foundations are good as long as the line is used for operation. The steel structure is good for almost an unlimited length of life. The conditions here are quite different from what they are in New York. There the lines were built in the early days and had very light locomotives. The size of the locomotives was increased, and the structure was too light. Then heavier electric motors were put in operation, and the structure was again too light. It was reinforced a number of times, but in spite of

that the original steel structure is still in use in the city of New York.

It is interesting to see the large proportion of the telephone system which has a comparatively short life, and the large part of it which is subject to obsolescence as compared with an elevated railroad. The elevated railroad is at an advantage also over surface electric lines because the elevated line has a very much smaller part of the total investment in a type of equipment which will depreciate rapidly. A very large part of the elevated railway cost is in right-of-way, which will appreciate rather than depreciate. As a matter of fact, the appreciation of the real estate will very nearly take care of the depreciation of the physical parts of the structure and equipment that are subject to fairly rapid depreciation.

Prof. Wodworth: We thank Mr. Seely for that statement. I think that shows a parallel line which is certainly very interesting. We who are watching what is going on in the telephone field, people who are operating the telephones, are quite sure that we know the system must be taken care of. As an illustration, we will suppose a certain sub-station with a local board. At the end of five years the subscriber is notified that he is entitled to a better type of board; the company come forward of their own initiative, take out the old board, put in a new one, go over all instruments, put everything in good shape so that it looks just as though it were brand new, and take out just one-half of the equipment. Of course, I take it, from the figures given, that the equipment in the local stations does not represent a very high portion of the total expense of the plant; still, it shows that there is an expense and it is being taken care of, and I understand from the statement of the officials of the company that this is what they expect to do, and that they are not doing any more than they expected to do. Am I right in saying that that represents part of the annual replacement, that is part of the scheme?

Mr. Smith: Yes, that is the idea.

Prof. Woodworth: Can you give me an estimate of the amount of investment represented by what I believe is called P. B. X. boards?—a local plant for house service.

Mr. Smith: Do you mean the sub-station equipment?

Prof. Woodworth: No, I mean simply the boards or house equipment; private exchange boards, and that sort of thing. Does that represent any large portion of the total?

Mr. Smith: That represents only a part of what I have put down under subscribers' stations and private branch exchange terminals. In the particular plant which I have considered, the two together made about 18%, of which I suppose not more than one-third—probably nearer one-sixth—would be private branch exchanges.

Prof. Woodworth: Of that 18% we would assume that a renewal every five years would be one-third of that 18% on that part of it alone.

Mr. Achatz: I happen to be in close touch with that figure, and I think it is about 11% of 18%.

Prof. Woodworth: To take care of that?

Mr. Achatz: Of the branch exchange switchboards only; somewhere in that near neighborhood, in Chicago.

Prof. Woodworth: Mr. Rice, haven't you something to say?

R. H. Rice, M. W. S. E.: Mr. Seely remarked that he did not know anything about the telephone but knew something about elevated roads. I do not know anything about telephones or elevated roads, but in connection with surface lines there are some points that might be of interest. The ordinance under which the surface railways are now operating requires practically complete rehabilitation of all the surface lines in the city, and the companies were allowed three years to do the major portion of this work. For the period following those three years, which are now past, there are certain provisions in the ordinance with regard to renewals and maintenance, the chief one of which is that there shall be set aside from the gross receipts 8% for renewals and depreciation, and that at least 6% shall be expended for maintenance and repairs. Also, if such 6% is not expended in any year, the unexpended portion thereof shall be deposited in a fund for subsequent use.

At the present time renewals are comparatively small, but in order to keep a street railroad system, as a telephone system, in proper working condition, it will be necessary to expend an approximately equal amount of money every year, and that probably was the basis upon which those terms were placed in the ordinance. If by any chance 8% should not be enough for renewals, the additional amount would have to be provided by the company from funds other than gross receipts. These provisions of the ordinance take away from the public utility companies at least one of the main incentives for keeping their renewal and maintenance costs down to just as low a point as the public will stand.

We have some problems in street railway work, in regard to determining the proper rates of depreciation to give the particular parts of the equipment, and the proper amounts to set aside for the renewals, as in the telephone business. It is also a difficult question to know, at times, where the dividing line is between maintenance and renewals. That is one of the really serious difficulties in the practical carrying out of any terms such as this ordinance specifies. It has been solved, in a measure, in the street railway ordinance by defining a renewal as the replacement of a principal part, and by having a clause in the ordinance that the Board of Supervising Engineers shall deter-

mine what shall be called a "principal part." That is a principle which I think might be adopted in the telephone or any other utility of similar character. A principal part, as its name implies, is, in general, one of the main portions of the equipment. For instance, a certain length of pole line, a certain length of trolley wire, or a certain length of conduit is defined as a principal part. The replacement of that much of any one of those portions of the equipment is a renewal. The replacement of anything less than that principal part is not considered as a renewal and will have to be provided for as maintenance. If, for instance, an explosion occurs and damages a manhole, the repair of that manhole is maintenance; whereas, if it were necessary, on account of street improvements or other contingencies arising, to replace, we will say, a mile of conduit line with its manholes, that would be, properly, renewals and not maintenance.

The question of depreciation, then, so far as street railway properties are concerned, is covered, as I mentioned first, by practically a determination of a straight-line rate of depreciation, and setting aside each year a certain amount of money to provide for such depreciation. The questions of obsolescence and other depreciations of that kind have not disturbed us and I do not think they will disturb us very much in the street railway situation. Of course, there are new things coming up all the time, such as the introduction of the inter-pole motor, and new types of street cars; and all those improvements are recognized, brought forward, and put into use. But the natural wear and tear on equipment is so great that generally these new things can be brought in as new equipment, and the old equipment can be used and utilized until it is worn out, so that it is not necessary to set aside anything especially for obsolescence.

Mr. Smith: The question of nickel-first telephones here in Chicago has been mentioned, and I would like to call attention to that subject as a good example of the result of municipal requirement or legislation on compulsory replacement. The Chicago Telephone Company has a certain number of nickel-first telephones in operation, which are said to show an operating advantage; that is, they can be operated at less cost than nickel-last telephones; however, the company may not only have to give up the installation of these telephones, but perhaps take out those that are already in, to satisfy the municipal authorities.

Prof. Woodworth: It seems to me we ought to have discussion of this subject from the broadest possible standpoint, from a man who is an engineer in all the general lines, but does not look at it from the narrow standpoint of an elevated man or a surface man or a telephone engineer.

Mr. Bement, haven't you something to say in regard to this subject?

A. Bement, M. W. S. E.: I am glad the "nickel-first" telephone has been mentioned, because it is a subject which I think is not well understood. In my first experience with that form of telephone, I thought it was most desirable and a great convenience. It was a pleasure to take up the receiver, hear the click, put in a coin or slug, and then talk with the party. In my opinion it is much better than to have the operator say "drop a nickel" after you begin talking with your party, to be followed by noise and confusion, which is an interruption to conversation. At that time I felt that it would be to the advantage of the public if the telephone company would change all of the nickel-last instruments to the pre-payment form. It is true, I suppose, that there is some objection to a situation where a person has not a nickel or a slug, and wants to talk, but I suppose that is like anything else, if we haven't the price to pay for it we may not get it. But taken all together, I think that the nickel-first telephone is a very desirable thing, and personally I would like to see all of the nickel-last telephones changed to the nickel-first form.

In reference to obsolescence, I believe it is probably a more important factor than we realize. About 20 years ago there were some establishments along Canal and Clinton streets which dealt in second-hand boilers, engines, and machinery, and a considerable amount of business was transacted. If a man wanted to put in a power plant he used to go into that district and see if he could not find something, and in the majority of cases he did. If a man had an engine or a boiler he wanted to dispose of, he found somebody to buy it. The dealers did not buy the material as junk; they bought it as a piece of machinery. That business has practically disappeared in recent years. There has been some very good steam-engine and some very good power-house equipment sold as junk at so much per pound, because buyers demand a much higher character of apparatus than formerly, so the factor of obsolescence is of growing importance.

With reference to Mr. Seely's remarks about the elevated roads, it has occurred to me that these roads are confronted with some other features of obsolescence. For example, among other things there are obsolete power houses. There is also the system of hot water, or steam heaters on the Metropolitan cars. These things are a considerable aggregate, yet it is true, as Mr. Seely says, that the elevated roads have not been subject to much obsolescence.

Likewise, the surface railroads in the Metropolitan district have at least some four or five obsolete power houses. Within recent years especially we have come to a realization that it does not pay to employ equipment which must be operated at a loss.

W. J. Miskella, Assoc. W. S. E.: One of the things that

affects depreciation — certainly theoretical depreciation — is growth in population, and it has been mentioned before this Society several times that the Chicago Telephone Company and the American Telephone & Telegraph Company have a very good system for estimating theoretical population for a number of years hence. The telephone company estimated 20 years before, that the population of Chicago would be a certain figure in 1910, and it happened that the estimated figure came very close to the actual figure.

In Colonel Zinn's paper on "Chicago's Waterways," published in the Journal for April, 1912, the question arose of the probable population of the city of Chicago in 1950. Someone has estimated that in 1950 our population will be about 13,000,000. I am wondering if Mr. Smith can give us any insight as to how these figures may be arrived at.

Mr. Smith: I cannot tell you much about the estimates of population, except to say that the estimates of development or number of telephones which will be in use in a certain number of years are very thoroughly gone into. It is customary to make a house-to-house count, and estimate the character of people in each block in a city and what the chances are that they will have telephones a certain number of years in advance, which is in some cases as much as 20 years in advance.

Mr. Seely: There is one feature of obsolescence that I would like to mention here. As far as the railroad companies are concerned, they undoubtedly should consider the amount of obsolescence, but many of us cannot consider the matter, because we do not have the earnings to set aside proper funds to take care of obsolescence. Take the case of a street car company or an elevated railroad company, which are under contract to the city to perform a certain service for a fixed sum, and that contract extends over a long period—for instance, with the elevated railroads, fifty years. They agree to carry anybody between any two points on their system for the sum of five cents. If the earnings are not sufficient to set aside a fund to take care of obsolescence, they cannot consider the matter. The proper method of basing compensation for any service rendered is that which is being followed out to a certain extent in Chicago with the gas company, the Chicago Telephone Company, and the Commonwealth Edison Company. An endeavor is made to find the investment in the plant, to find how much money is necessary to operate the plant, and also how much is necessary to take care of obsolescence and replacements; the price for service rendered is then determined on such a basis as will insure a fair return on the investment and take care of these other items. That principle should be followed in all lines of public-service corporations. As far as I know, the only public-service corporations in the city that

do not have the compensation to a certain extent fixed along these lines are the traction companies. I believe it is only a matter of time until all over the country, instead of paying five cents for a ride on a city transportation system, no matter how far you travel, whether half a mile or fifteen miles, the fare will be three cents, four cents, five cents, seven cents, or eight cents, depending on the distance. This method will give the companies earnings sufficient to provide for the elements of obsolescence and replacements.

Donald Bowman: All plants of public service companies have the question of peak load to handle, and in the telephone business I wish to ask what factors of the service tend to make a peak and also what time of the day the peak comes.

Mr. Smith: I do not know that the question is connected directly with the subject of the paper, but I will say, with regard to the telephone peak, that it depends upon the character of subscribers. That is, the peak service for the downtown offices in Chicago will be somewhere in the middle part of the day, while the peak of offices in the outlying districts will be in other parts of the day, depending more upon calls of a social nature. I mentioned in my paper the fact that the telephone plant must be built to carry the peak of the load without any overload, and that is something which should be kept in mind. That is, there can only be one conversation on one pair of subscribers' wires, and the circuit which is used for a conversation must extend from the central office clear out to the subscriber, so that it does not allow of an overload.

CLOSURE.

Mr. Smith: Aside from the effect of rapidity of growth, the discussion brings out the great difference between the depreciation problem for telephone properties and for other electrical properties. Where the factor of obsolescence does not enter into the problem, the question of how much should be laid aside for depreciation is much easier to answer than where obsolescence is one of the most important factors, as in the telephone field. Judging from past experience, obsolescence will always be one of the chief causes of replacements of telephone apparatus.

The effect of rapidity of growth, as brought out in the paper, should be felt in all branches of the electrical industry, so that what I have stated in regard to this factor applies equally to telephone companies, traction companies, and electric light and power companies.

IN MEMORIAM.

WALTER KEITH MEANS, M. W. S. E.

Died April 17, 1912.

Walter Keith Means was born December 21, 1851, at Augusta, Maine. While he was still a child, his parents moved to Boston, where, with the exception of about two years, he remained until he was nearly forty years of age. After graduating from the English High School at Boston, he entered the Massachusetts Institute of Technology, graduating from the full civil engineering course in that institute in 1874.

For about five years after graduation he was employed on various engineering works in and around Boston. In 1879 he first went west, being employed on preliminary surveys by the Chicago, Burlington & Quincy R. R. for about one year. In 1880 he entered the service of the Chicago & Eastern Illinois R. R. as assistant engineer, where he remained until December, 1881. He then re-

turned to Boston, where he was employed as assistant engineer by the Boston Gas Light Company and its successors for about nine years.

But the "call of the west" proved too strong for him, and in 1890 be came to Milwaukee, where for several years he was associated with W. F. Goodhue in a general engineering practice, principally along the lines of sanitary engineering.

In 1896 he entered the U. S. Engineer Department at Large as assistant engineer, and practically remained in the Government service until his death. While in the Government service he was principally engaged in making hydrographic and other surveys, for which work he was eminently fitted.

During 1906-1907 he had charge of the survey of Lake Winnebago, Wisconsin. This was the first complete survey of the lake which had been made by the Government, and the careful work done by Mr. Means resulted in the preparation of the only reliable chart of the lake which has ever been prepared.

In 1905 he was connected with U. S. Lake Survey on surveys of the St. Clair river and elsewhere, and for a time was stationed at Port Huron, Michigan. In 1907, when it was decided to build a lighthouse at White Shoal in the northern part of Lake Michigan, Mr. Means was assigned to the work of making the necessary preliminary surveys. His work was done in a most thorough manner, although the difficulties in the way of making an accurate location were very great, the shoal being entirely submerged at all times and over ten miles distant from the nearest land.

During 1909 he was employed on the survey for the inland water route along the coast of Virginia and North Carolina; on the completion of this survey, he again returned to Milwaukee.

Mr. Means was married on October 4, 1910, to Miss Alice Newcomb at Manitomoc, Wisconsin, and since then to the time of his death he resided at that place. His death occurred suddenly on April 17, 1912, after an illness of only a few hours.

His predominant characteristic was accuracy. Carelessness of method and inaccuracy of detail were abominations which he could not endure. When a piece of work on which he had been engaged was completed, it was only after most careful revision and examination that he would finally certify to its correctness. In consequence, maps prepared and certified to by him were considered authoritative.

Mr. Means became an Active Member of the Western Society of Engineers March 11, 1901, and before his marriage was a frequent attendant at the meeting of the Society. Naturally a student, he was a man of general cultivation. He possessed a wonderful fund of knowledge outside of his professional work. He delighted in library research, and nothing gave him keener delight than to find some obscure fact in literature or history. He had a keen sense

of humor, and was ever on the lookout for oddities which he would carefully collect for the future entertainment of his friends.

In closing, it is only just to say of Mr. Means that under all circumstances, even the most trying, he was a gentleman. Those who knew him esteemed his friendship highly, and his sudden death was greatly deplored by all. Of him it can be truthfully said that those who knew him best, admired him most, and that the world was better for his having lived.

J. A. B. TOMPKINS,
L. M. MANN.
Committee.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, September 9, 1912.

An extra meeting of the Society (No. 791), the Bridge and Structural Section, was held Monday evening, September 9, 1912.

The meeting was called to order about 8:30 p. m. with F. E. Davidson, Chairman of the Section, presiding, and about 20 members and guests present.

There was no business to bring before the Section and the Chairman introduced Prof. O. H. Basquin, who presented his paper on "The Circular Diagram of Stress and Its Application to the Theory of Internal Friction." This paper had been printed and sent out in advance, so it was not read but was explained and commented upon by the author, with blackboard sketches, illustrating the creation and application of the circular diagram. As the evening was very warm there was no comment on the paper except from the chairman, and the meeting adjourned about 9:40 p. m.

Extra Meeting, September 16, 1912.

An extra meeting of the Society (No. 792) was held Monday evening, September 16, 1912. The meeting was called to order about 8:20 p. m., with Mr. C. B. Burdick presiding, and about 25 members and guests in attendance.

The chairman introduced Mr. Samuel A. Greeley, who presented his paper, with lantern slide illustrations, on "The Principles of Municipal Refuse Collection." The paper had been printed and sent out in advance, and was not read in full, but presented in abstract. Discussion followed from the chairman, J. L. Jacobs, F. H. Cenfield, W. E. Symons, C. C. Saner, A. B. Segur, A. Bement, with a closure from Mr. Greeley.

Meeting adjourned about 10:10 p. m.

Extra Meeting, September 23, 1912.

An extra meeting of the Society (No. 793) was held Monday evening, September 23, 1912. The meeting was called to order at 8:25 p. m., with Vice President A. Bement in the chair, and about 45 members and guests in attendance.

Mr. Joseph Harrington, M. W. S. E., was introduced, who read his paper on "Furnace Efficiency." The Secretary read a contribution from Dr. W. F. M. Goss, in discussion of the paper. Mr. Bement presented some discussion, with lantern slide illustrations. Further discussion was offered by Messrs. T. A. Marsh, T. A. Peebles, W. L. Abbott, J. C. Peebles (Armour Institute), Osborn Monnett, L. M. Ellison and A. J. Saxe, with replies and a closure from Mr. Harrington. Dr. Conrad Matschoff, of Berlin, was present and made some remarks on his visit to this country in the interests of engineering education.

Meeting adjourned at 10:30 p. m.

Regular Meeting, October 7, 1912.

A regular meeting of the Society (No. 794) was held Monday evening, October 7, 1912. The meeting was called to order about 8:25 p. m. by President Armstrong with about 55 members and guests in attendance.

The Secretary announced the deaths of Horace E. Horton, Past-President, July 29, 1912, and Charles L. Harrison, M. W. S. E., September 15, 1912. The Secretary reported from the Board of Direction that the following had applied for membership in the Society:

Walter S. Cadwell, Chicago.
Julius Reed Hall, Chicago, transfer.
Walter S. Lacher, Chicago.
Robert D. Townsend, Chicago.
Frank Stanley Musser, Chicago.
A. H. Cameron, Minneapolis, Minn., transfer.
Vernon H. Aiken, Fargo, N. D.
John Henry Spengler, Chicago.
Lucian G. Blackmer, Chicago.
Clarence W. McFerron, Sallisaw, Okla.
Edward H. Ashdown, Chicago Heights, Ill.
Samuel Dauchy, Chicago.

Also that at their meeting of October 1, 1912, the following had been elected into membership in the Society:

Henry G. Tyrrell, Evanston, Ill. .... Member
H. S. Baker, Marshfield, Wis. .... Junior Member
Roy Shackleton, Chicago .... Associate Member
George W. Hand, Chicago .... Member
W. H. Roney, Jr., Geneva, Ill., transferred to .... Associate Member
Earl L. Wood, Chicago .... Associate Member

The President then introduced Prof. Albert Smith, of Perdue University, Lafayette, Ind., who presented his paper on "Wind Pressure on Buildings." The Secretary read a communication from Prof. H. P. Boardman, M. W. S. E. Further discussion and explanations were made by Prof. Smith, Mr. Armstrong and S. T. Smetters.

The meeting adjourned at 9.20 p. m.

Extra Meeting, October 14, 1912.

An extra meeting of the Society (No. 795), being a meeting of the Bridge and Structural Section, was held Monday evening, October 14, 1912.

The meeting was called to order at 8:30 p. m., with Mr. W. W. Curtis presiding, and about 35 members and guests in attendance. The reading of the minutes was dispensed with, as they had been published, but the Secretary read a letter from Prof. A. N. Talbot, University of Illinois, dated October 11, 1912, as follows:

"The discussion on compression members, printed in the September Journal of the Western Society of Engineers, shows the interest of the members of the Society in the subject of column action. The University of Illinois Engineering Experiment Station, Department of Theoretical and Applied Mechanics, has for some time had under consideration the making of further tests and investigation on compression members, and has planned to make a series of tests during this college year. In view of the interest expressed, it would seem that some phases of the column investigation might well be undertaken under a coöperation of the Society and the Engineering Experiment Station. You know in a general way the facilities of the Laboratory of Applied Mechanics. We appreciate the advantages there would be in the help of men who are engaged in engineering practice, and it seems probable that a moderate amount of testing may be done by the University along lines which will add to the knowledge of column action. Tentative plans have already been made for some of our work, but these may be modified or extended. We are ready to start immediately on a limited amount of work.

"I wish to suggest the appointment of a committee by the Structural Section to consider and report upon the advisability of action on this matter. If this committee is not appointed, I wish to ask for general suggestions in writing from any member of the Society who may be

interested in the matter. If such a committee is appointed, I shall be glad to meet it and discuss the project."

A motion was offered by Mr. Davidson that this matter be referred to the Board of Direction for action, with the suggestion that the importance of the matter warrants prompt action.

The subject for the evening was stated by the Chairman as "Small Industrial Plants." Mr. F. E. Davidson read his paper, with some lantern slide illustrations, and was followed by Mr Andrews Allen, describing, with the aid of steropticon views, another and different industrial plant. Some little discussion followed from Messrs. W. W. Curtis, F. D. Chase, S. T. Smetters and F. E. Davidson.

Meeting adjourned at 10:15 p. m.

J. H. Warder,
Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY

Reinforced Concrete Construction. Volume I. Fundamental Principles. By George A. Hool, Associate Professor of Structural Engineering, University of Wisconsin. McGraw-Hill Book Co., New York. 1912. Cloth; 6½ by 9½ in.; pp. 254, including index. Illustrated. Price, $2.50 net.

This 254 page volume is the first of a series of three volumes on Reinforced Concrete Construction. Volume I treats of fundamentals in design. Volume II is to treat on detail designs of retaining walls and buildings, and Volume III is to discuss detail designs of bridges and other structures.

These books are a compilation and elaboration of a course in reinforced concrete construction given by the Extension Division of the University of Wisconsin, and have been "written primarily to meet the needs of those who desire to take up the study of this subject by correspondence." The treatment of the subject "presupposes a knowledge of the elements of structures." A large amount of the theoretical treatment follows closely "Principles of Reinforced Concrete Construction" by Turneaure and Maurer, to which the author gives credit.

There are nine chapters treating subjects: "Concrete" 22 pages; "Steel" 4 pages; "Concrete and Steel in Combination" 13 pages; "Rectangular Beams" 97 pages; "Slabs, Cross-beams and Girders" 32 pages; "Columns" 20 pages; "Slab, Beam and Column Diagrams" 26 pages; "Bending and Direct Stress" 9 pages. In each chapter there are a large number of illustrative problems.

Taking up points noted by the reviewer in their order of occurrence, one notices at the start that the book is written from the theoretic standpoint with little or no consideration to practical limitations. This is very well for the experienced man, but it is decidedly not well for the larger class of readers of the book. If anywhere, theory should be adjusted to practical conditions, it is in reinforced concrete, until such time as practice can be brought up to within shouting distance of the accuracy now attained in design. For instance, the author states that loam should never be permitted in sand. The young reader who takes this to heart will have many an anxious day. While the mechanical analysis discussion is excellent, the young enthusiast might have saved hours of useless labor, if the statement had been made that it is a rare thing to select proportions for maximum density in the manner named, unless the job is of considerable magnitude, warranting an equipment to carry a uniform degree of accuracy throughout the entire operations of construction.

Waterproofing Qualities of Concrete is a paragraph of much importance and should have fuller treatment. Page 23 displays a plate of six types

of deformed bars. Two of these have not been manufactured for more than a year and two others are rarely seen in the western market, whereas other bars in common use are omitted. The author's statement as to size of bars in commercial use is misleading, as the 1-16 in. sizes, if carried in stock at all, are in small quantities; also sizes over 1¼ in. in diameter are difficult to get, and while larger sizes are sometimes shown on plans, they are almost invariably changed to smaller sizes by the contractor. The usual sizes vary by ⅛ in. from ¼ in. to 1¼ in. This is especially true of all deformed types except the twisted bar, which may be had in the 1-16 in. sizes if one has time to wait for the mills to roll it. The statement that "medium steel is manufactured and sold under standard conditions . . . and engineers can feel sure of safety . . . without tests," is showing a dangerous confidence in the manufacturers of today. "Exhaustive" tests may not be necessary but anyone who buys steel, medium or high carbon, otherwise than under standard physical tests, is taking more risk than most engineers acquainted with manufacturing conditions care to take. Steel should never be specified or bought except under standard physical tests suited to the grade.

The reviewer disagrees with the author and considers him a little inconsistent in his position upon the use of high elastic limit steel for reinforcement. The reviewer has several hundred tests, conducted under his own supervision of "old rail stock," and feels entirely safe in using that steel under certain limitations.

The theoretic discussion, following closely "Turneaure and Maurer," is excellent, although there seems to be an assumption of too much knowledge on the part of the readers it is intended to reach. The examples, however, help this difficulty.

Figure 65, page 133, shows a continuous beam with its support, with consequent cracking of the concrete. After the careful previous treatment of shear, one wonders if the author uses his formula for this condition without modification.

The author speaks of obtaining greater economy in irregular spacing of bars in a two-way reinforced slab. Often designers have an ordinance within the provisions of which it is necessary to keep, and when a reduction in the amount of steel is allowed by closer spacing at the center, it is not wise to use more than two spacings, one for the center section and one for the sides, for the men will disregard the specifications, and, in fact, it is not necessary. As for economy in the use of steel, under present conditions of competition one may be sure that every possible economy, real and imaginary, is sought out to get orders. This does not necessarily mean ultimate economy, for very often it means a more expensive design, but the salesman for some patented deformity is selling steel.

The discussions on economical proportions are good, but not comprehensive enough, and are without sufficient caution to the student. Economy for the completed structure depends upon many other things besides the material entering into the immediate member in question. Dimensions of buildings are fixed, and frequently column spacing is fixed by the requirements of the building. To design each beam or column without regard to others in the floor might mean unnecessary expense, or to design each floor without reference to other floors would also lead to excess expense. Dimensions of parts, lengths, bends, and number of steel bars should be kept as near uniform as consistent with the thought that quite often one foot of a ⅝ in. square bar is equivalent in value to two minutes of a man's time, and that 1 cu. ft. of concrete is equivalent to about 15 minutes of a carpenter's time. Also that the slight variation in steel or concrete not only takes time for one individual but several, with consequent increased liability to error.

Effect of forms on economy receives no consideration, yet all workers know, often through dear experience, their importance. According to

Waddell, "simplicity is the highest attribute of good design," and if this is true in steel construction under skilled workmen with mechanical accuracy, how much more is it true of reinforced concrete where mechanical accuracy is an unknown quantity, and the "that is good enough" policy predominates. Simplicity in design can hardly be too strongly urged. Our designing methods are far in advance of construction methods, and what is most needed now is more knowledge of working conditions and limitation with workable and then inflexible specifications. Many writers of specifications, including architects and engineers of reputation, do not see the details of their work carried out, and therefore do not have the opportunity to modify their specifications to make them workable.

The author recommends pipe-sleeves for column rod connections. This method the reviewer tried years ago and abandoned it, and in other instances where he has seen it used it is inviting a condition of weakness. Theoretically, it looks excellent, but practically, it does not work. Rods are sometimes sawed and sometimes sheared off at ends with a consequent lip or protruding points which make any attempt to end bearing impossible, unless the rods are milled or ground. And when milling or grinding is definitely and explicitly specified, ten chances to one the contractor takes that as a bit of theory that is not necessary to follow, and even if the rods are properly ground they are rarely set vertical, especially the rod bent to come within the limits of a column smaller than the one below. Considering it sufficient that one-half to three-quarters of the end surfaces were in contact for direct bearing, there is the possibility of a dangerous condition of eccentric loading. One can be perfectly sure that the pipe will not be over one-quarter filled with grout, if filled at all.

There is nothing said about cold-weather concrete, pressure on forms from wet concrete, design and removal of forms, wearing surfaces for floors, and many other points of vital interest to the beginner. Doubtless these will be treated in future volumes. Some of the tables are useful, but others, with most of the diagrams, appear to be of little practical value. The book, as a whole, is well set up and will be found useful to many, yet the reviewer cannot avoid the feeling that the writer has left a big important side—the practical—untouched. After the inexperienced and inefficiently trained man has finished this course, he then considers himself competent to undertake the design and supervision of construction of any kind of a structure, little recognizing that practical conditions are not ideal and that some over-sight or blinded-sight produced by an enthusiastic, but thoughtless, foreman may cause the loss of lives and property. Workable, inflexible rules must be formulated for workmen, foreman, superintendent, and manager of construction, and the young or old man who takes up the study of this subject should be made to feel that no correspondence course or set of books can teach him all.

The reviewer has had twelve years' of experience, much of the time in direct, intimate touch with the work, and is perfectly willing to admit that there is yet much for him to learn. W. A. H.

Treatise on Hydraulics. By Mansfield Merriman, assisted by Thaddeus Merriman. John Wiley & Sons, New York; and Chapman & Hall, London. 1912. Ninth edition, revised and reset. Cloth; 6 by 9 in.; pp. 565, including index. Illustrated. Price, $4.00 net.

This work is a revision and slight enlargement of Prof. Merriman's well-known treatise originally published in 1889, and since revised in eight editions and twenty reprints.

This work has so long been a standard treatise on hydraulics, and is so familiar to most engineers and students, that extended comment is superfluous. It has been the practice of the author to continually revise and improve the book, particularly to take advantage of additional knowledge that has been gained from time to time through experiment or to describe

new apparatus. In this edition the type has been entirely reset, the arrangement of the subject matters slightly changed, and about six per cent of new matter has been added. The tables appended to the subject matter in former editions, have been distributed through the text, and correlative matters not necessary to an understanding of the subject, are printed in smaller type, thus making the book more easily read and consulted. The new matter is as follows:

To the chapter upon instruments and observations has been added a more extended description of the Venturi meter, the Pitometer and the Pitot tube. On circular orifices, the coefficients deduced by the experiments of Judd and King, and by Belton, have been added to the tables, formerly published, by Hamilton Smith. A short article on oblique weirs has been inserted, summarizing the meager existing data. Upon submerged tubes, the experiments of Stewart of the University of Wisconsin, are reviewed and summarized. An article has also been added treating of fountain flow, based on experiments of Lawrence and Bromworth.

An article on regulating devices illustrates and explains the air valve, relief valve, pressure reducing valve, and in filter apparatus, the controller and the lost head gauge.

In the chapter on conduits, the principal experiments on the flow in steel and wrought-iron pipes have been summarized. A tabulation of experiments has been made showing the effect of age on the friction coefficient in cast-iron pipe, but no attempt has been made to formulate these data.

The treatment of the back water from dams has been extended by the addition of a second approximate method of computation. A small amount of new matter has been added in reference to dams, rainfall, evaporation and runoff. This work is essentially a treatise on theoretical and practical hydraulics and, as proper, all other features of the matters treated are subordinated to the hydraulic features. The references to rainfall and its disposal, and water works and water power are very elementary, the subject matter being confined to the hydraulic essentials. A valuable feature is the more numerous references to the sources of the information. This feature of the work might be extended to advantage, particularly in reference to those subjects receiving elementary treatment, where the reader might profitably pursue the matters further.

To those who are acquainted with the writings of Professor Merriman, it is needless to say that the book is clear, concise, and logical, well edited and exceptionally well printed. C. B. B.

Electric Central Station Distribution Systems, Their Design and Construction. By H. B. Gear, A. B., M. E., and P. F. Williams, E. E. New York. D. Van Nostrand Company, 1911. Cloth; 8¼ by 5½ in.; vii + 347 pages; 139 illustrations. Price, $3.00.

This book by Messrs. Gear and Williams fills a void in the broad consideration of the engineering aspects of the central station industry. Considerable has been written on power-plant development and high-tension transmission. There are available some books on low-tension networks and storage batteries, and occasional papers in the proceedings of the engineering societies and electrical associations dealing with parts of the distribution equipment, but until now there has been no comprehensive treatment of the modern distributing systems of large central stations, such as are found in our principal American cities.

The book opens with a general discussion of the different systems of distribution and classes of substations, and takes up the methods for securing voltage regulation. Then follow several chapters on line transformers, laying out and calculation of secondary distributing networks, special schemes of transformation, and various classes of protective devices, such as fuses, circuit breakers and lightning arresters. Overhead construction is taken

up as to poles, insulators, line wire, accessories, etc., and the construction of overhead lines. Underground construction is similarly treated as to conduits, manholes, cables, etc. A particularly interesting chapter is that devoted to distribution economics, some of its topics being: Selection of economic sizes of conductors, minimum annual cost and fixed charges, calculation of losses, diversity-factors of different classes of consumers and at different points in the system. The last two chapters, dealing with the properties of conductors and the characteristics and calculation of alternating-current circuits, are almost in the nature of appendices, but are valuable in supplementing the preceding general discussion.

Throughout the book the treatment is very simple and clear and devoid of abstruse mathematical expressions, although many algebraic formulae are given for facilitating various calculations. Elaborate details are avoided and the entire discussion, because of its logical arrangement, is easily followed. A very pleasing feature of the book consists in the historical introduction to the several main branches of the subject, which throw a flood of light on the evolution of the practice that now prevails on the largest and most successful central station systems.

Although the distribution network is not a spectacular part of the entire central station system, it is a very essential part and requires sound engineering skill and judgment in its design and construction. It is therefore fortunate that two busy engineers, connected with the largest urban central station system in this country, have found time to record, in permanent form, the principles and best practice of electrical distribution engineering.

F. H. B.

The Official Good Roads Year Book of the United States. The American Association for Highway Improvements. Colorado Building, Washington, D. C. 1912. Cloth; 6 by 9 in.; pp. 406. Price, $1.00.

This is a valuable book containing as it does a concise digest of the road laws of all the States; also a list of road contractors in the United States, a full bibliography of books, pamphlets, papers, etc., pretaining to road building and maintenance; a list of colleges teaching highway engineering and their course of instruction; a list of organizations working for road improvement; a directory of highway officials in the United States; a list of manufacturers of road machinery and materials; and a list of patents issued in 1911 relating to roads.

The personnel of the Association for Highway Improvement is of high grade—with L. W. Page, Director, U. S. Office of Public Roads as President; W. C. Brown, President of the New York Central Railway Lines, as Vice President; James S. Harland, member Interstate Commerce Commission, as Chairman. Board of Directors: J. E. Pennybacker, Jr., as Secretary, and Charles P. Light, as Field Secretary.

The book opens with a History of Road Building, giving a statement of Ancient Road Builders; the Romans as Road Builders, and the French as Road Builders; then comes a section on Toll Roads and a historical Sketch of Great Road Builders. This is followed by a more detailed statement of the Association with list of officers, the Object of the Association, Constitution and By-Laws, and a long list of members. The chapter on Road Legislation in the United States, and of the several States (arranged in alphabetical order, so any State may be readily found) is very complete, containing as it does 147 pages. Types of roads, covering 20 pages, is full of valuable information. This is followed by shorter chapters on Road Maintenance and Repair; Dust Preventers; and Highway Bridges and Culverts, with illustrations. There are 39 pages devoted to Bond Issues, Appropriations and Mileage, in many different States, which are of value to the statistician and student of political economy.

The matter of Convict Labor on the Public Roads, is given some 17 pages, showing the policy and practice of many of the States. It seems

eminently right that those who have broken the laws and must be kept under restraint, for a longer or shorter period, and hence are a charge on the State, should make some return to the State in the way of useful work, that is of benefit to all of the tax-payers in that State.

In the bibliography on road building is given a list of the Bulletins, Circulars and Documents, issued by the Office of Public Roads, U. S. Department of Agriculture, and also a list of publications issued by the several States. Such a book as this should be in the hands of all those who are interested in Good Roads.

Reinforced Concrete Buildings. A Treatise on the History, Patents, Design and Erection of the Principal Parts Entering into a Modern Reinforced Concrete Building. By Ernest L. Ransome and Alexis Saurbrey. McGraw-Hill Book Co., New York. 1912. Cloth; 6 by 9 in.; pp. 235, including index. Illustrated. Price, $2.50.

This book is in three parts. Part I treats of the History of Reinforced Concrete Construction in two chapters—Personal Reminiscence by Ernest L. Ransome, and a Short Survey of the Early History of the Art and Basic Patents. Part II, Rational Design of Reinforced Concrete Buildings, is covered in seven chapters—Introduction. Adhesion. Compression and Lateral Expansion. Bending. Transverse Stresses. Applications of the Bending Theory. Initial and Allowable Stresses. Part III, Practical Construction is treated in ten chapters—Materials of Construction. Floor Systems. Foundations. Finishing Operations. Fireproofing and Fires. Repairs to Existing Buildings. Accidents. Superintendents' Specifications. The Engineer. The Theory of Beams as Illustrated by Tests.

The entire subject is treated in 230 pages. Personal reminiscences are often profitable reading, especially when the writer has been connected with an industry as long as Mr. Ransome, and many who know of his early work will read this chapter with interest.

It is also a good thing to collect some of the more important patents in a brief summary.

If the book had appeared eight years ago, it would have had a prominent place in the literature of the subject, but at present the reviewer sees but a small field of usefulness. One's own personal experience and views are of course of more interest to him than the work of others, yet in a book claiming to treat a subject in a broad way, most readers look for information devoid of personal bias of a strong flavor of commercialism.

The reviewer is glad to note greater emphasis (than is usually the case in books) placed upon the importance of construction methods, and the supervision of the field work, and is pleased to see his own ideas confirmed in the statement that the real problem at the present time is to get satisfactory workmanship. W. A. H.

Artistic Bridge Design. A Systematic Treatise on the Design of Modern Bridges According to Aesthetic Principles. By Henry Grattan Tyrrell. With an Introduction by Thomas Hastings, of Carrere & Hastings, Architects The Myron C. Clark Publishing Co., Chicago. 1912. Cloth; 6 by 9 in.; pp. 294, including index. 242 illustrations. Price $3.00.

This 290 page book covers the subject in twelve chapters—Importance of Bridges. Reasons for Art in Bridges. Standards of Art in Bridges. Causes for Lack of Art. Special Features of Bridges. Principles of Design. Ordinary Steel Structures. Cantilever Bridges. Metal Arches. Suspension Bridges. Masonry Bridges. Illustrations and Descriptions.

The print is good and the illustrations clear. There is certainly need for a book of this nature of the present time, and we are glad that some one has taken the initiative in treating this subject in the comprehensive way which it deserves.

The illustrations are an interesting and valuable collection, yet we

wish that with many of these general views there were other closer views, showing interesting details; also that the descriptions following the views were more complete in many instances. To illustrate—on page 216 is shown an arch bridge which had special artistic treatment. The soffit of the arch had a mortar finish, composed entirely of marble chips. The spandrel walls had a surface mortar composed of about half rock and half marble chips. These surfaces were then tooth-chiseled with a coarse chisel, giving a rough cast appearance, and removing all board marks and the color of cement. The balustrades and ornamentation were composed of an artificial stone, of selected material, and were given special surface treatment.

We notice, in passing, that an error has crept in on page 211, where it states that the Zanesville "Y" bridge was designed by the Osborne Engineering Co. Mr. Edwin Thacher designed this bridge, and the Osborne Engineering Co. were supervising engineers. I might also state in this connection that Mr. Thacher should have been given credit for the design of many other bridges shown. Throughout the book Mr. Thacher's name appears obscurely once, whereas the writer refers to the designs of Henry Grattan Tyrrell and the "author" no less than thirteen times. Many other prominent bridge engineers either do not appear at all, or are but casually mentioned. Of course the purpose of the book is not to advertise any individual engineer or architect, so names are only incidental.

One is apt, however, in reading some recent productions of engineers to question if they are not a little deficient in some other respects as well as in artistic treatment of inanimate material. Modesty with humans is possibly as attractive a characteristic as art in bridges.

Further, we would like to see the name and location of the bridge illustrated in the text printed directly below the illustration. Adverse criticism is easy, yet it may aid in the development of books as well as bridges.

The reviewer is glad for the opportunity to go through this interesting book, and has received, in suggestion, from this casual review, many times its value. W. A. H.

LIBRARY NOTES

The Library Committee desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

Myron C. Clark Publishing Co.:
Artistic Bridge Design, H. G. Tyrrell. Cloth.

McGraw-Hill Book Co.:
Transmission Line Construction, R. A. Lundquist. Cloth.

George C. Hooker, Chicago:
Proceedings, Second National Conference of City Planning, 1910. Cloth.

EXCHANGES.

Illinois Bureau of Labor Statistics:
Fifth Annual Report, 1911. Cloth.

International Railway Fuel Association:
Proceedings, Fourth Annual Convention, 1912. Pam.

Connecticut Society of Civil Engineers:
Transactions, 1911. Pam.

American Society for Testing Materials:
Proceedings, 1912. Paper.

American Society of Mechanical Engineers:
Transactions, 1911. Half leather.

Indiana Sanitary and Water Supply Association:
Proceedings, Fifth Annual Convention, 1912. Pam.
Western Railway Club:
Proceedings, 1911-12. Half leather.
Institution of Naval Architects, London:
Transactions, 1912. Cloth.
New York State Engineer and Surveyor:
Annual Reports, 1910 and 1911. 3 vols., cloth.

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Harrison, Charles L.................................September 15, 1912

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THE CIRCULAR DIAGRAM OF STRESS AND ITS APPLICATION TO THE THEORY OF INTERNAL FRICTION

O. H. Basquin, M. W. S. E.

Presented before the Bridge and Structural Section
September 9, 1912.

The circular diagram of stress was devised many years ago by Professor Otto Mohr*[1], of Dresden. The simplicity of the method, and the facility which it gives for the solution of problems, are strong inducements for its universal use among engineers. In this paper an attempt is made to give the method a straightforward explanation which begins at the beginning, and afterwards to illustrate its use by working out certain problems in the application of the theory of internal friction to the yield stresses of ductile materials and of earthy materials, both with and without cohesion. Some of these solutions are old and some are believed to be new.

MOHR'S DISCUSSION OF STRESS.*[2]

We wish to discuss the conditions of stress in a medium which is homogeneous and isotropic, *i. e.*, it is alike in all parts, and, at every point, it has the same properties in all directions. Most materials do not meet these assumptions completely; wood is made up of hard and soft layers, and its strength is quite different across the grain from its strength along the grain. A steel plate has slightly different properties in the direction of rolling and at right angles to that direction, and a railway rail has somewhat different properties in the thick head and in the thin web. For this discussion, however, such differences will be neglected.

We assume, further, that the variation of the stress in the medium is *continuous,* both in amount and in direction, *i. e.*, there are no sudden changes in stress. A block resting on a table may be supported by a uniformly distributed stress over the lower face of the block, but on the table this distribution of stress has sharp

*1—Zivilingenieur, 1882, p. 113, or Mohr's Technische Mechanik, p. 187.

*2—This discussion follows Mohr's thought but is not a translation.

limits, at which the stress changes suddenly from zero to a considerable magnitude. The stress distribution on the table top is discontinuous and is ruled out of our discussion. On the other hand, at a small distance below the surface of the table, the stress distribution is doubtless continuous and falls within our assumptions. The stress here varies from point to point, both in direction and amount, but it varies slowly.

Let us designate the point in the medium under discussion as point *J*, and let us imagine a small sphere drawn about this point. Fig. 1. We wish to study the stresses on various planes drawn through the point *J*, but instead of drawing the planes through *J*, we shall draw them all tangent to the sphere, and then let the sphere diminish in size. In this way we may make the planes approach the point *J* as closely as we please, and their stresses will approach those of planes actually drawn through the point *J*. We may designate these planes by the radii drawn from *J* to their points of tangency; thus planes *r* and —*r*, Fig. 2, are tangent to the sphere at opposite ends of the same diameter. They are parallel, and, if the radius *r* is very small the stresses on these two tangent planes are practically the same, both in direction and in magnitude.

About our sphere let us draw three sets of tangent planes,

Fig. 1

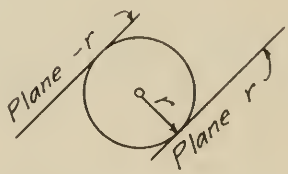


Fig. 2

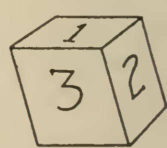


Fig. 3.

each set consisting of two parallel planes drawn at opposite ends of the same diameter, Fig. 3. Planes r_3 are parallel to the paper, while planes r_1 and r_2 are at right angles to the plane of the paper. These planes inclose an element of volume about the point *J*, and all the six faces of this element of volume are of equal area, ΔA. The stresses on the three sets of faces will be represented by f_1, f_2, and f_3, of unknown directions, but the stresses on opposite faces are equal in magnitude, parallel in direction, and opposite in sign. The corresponding forces on the faces of the element will be $f_1\Delta A$, $f_2\Delta A$, and $f_3\Delta A$, respectively. Since the dimensions of these faces are infinitesimal, the stress distribution will be uniform over each face, so that the forces will act as if concentrated at the center of gravity of each face, as shown in Fig. 5.

We may begin by finding the moment of all forces of this element of volume about the radius r_3, which is drawn through the point *J* at right angles to the paper. We may first notice that the force $f_3\Delta A$ has no moment about the radius r_3 because its line of action intersects the radius r_3.

[The angle between any two lines s and t, Fig. 4, may be represented by the symbol (st); and we shall consider angles positive when measured in a clockwise sense.]

If b is the length of one edge of our element of volume, Fig. 5, the moment about radius r_3 of the couple formed by the two forces $f_1\Delta A$ is $b.\ f_1\Delta A\ cos\ (f_1\ r_2)$; and the moment about radius r_3 of the two forces $f_2\Delta A$ is $-b.\ f_2\Delta A\ cos.\ (f_2\ r_1)$. For equilibrium of the element we must have this sum equal to zero, or

$$b.\ f_1\Delta A\ cos\ (f_1\ r_2) - b.\ f_2\Delta A\ cos.\ (f_2\ r_1) = O.$$

From this equation the factors b and ΔA may be cancelled, so that we have, after transposing,

$$f_1\ cos\ (f_1\ r_2) = f_2\ cos.\ (f_2\ r_1) \qquad \text{Eq. 1.}$$

This is our fundamental equation, from which follows practically the whole of the following discussion. It may be expressed in words as: *The projection of the first stress upon the second radius equals the projection of the second stress upon the first radius.*

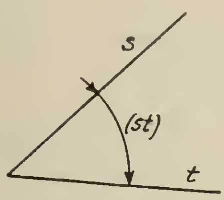


Fig. 4

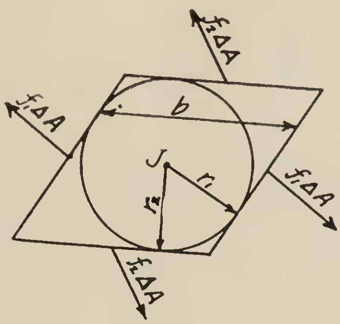


Fig. 5

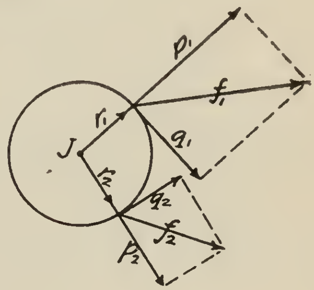


Fig. 6.

It may be noticed that we have not assumed that the lines of action of $f_1\Delta A$ and $f_2\Delta A$, Fig. 5, are in the plane of the paper; in general they are not in that plane. Likewise $b.\ f_1\Delta A\ cos\ (f_1 r_2)$ may not be the maximum moment of the couple made by the forces on the r_1 faces, but that expression is their whole moment about the radius r_3, and that is what we have been discussing. The remainder of this moment, if any, is in a plane parallel to the radius r_3, and will be equilibrated by a portion of the couple given by the forces on the r_3 faces.

Since we are now dealing with stresses instead of forces, there is no need of placing their vectors at the centers of the faces, and the faces themselves may be omitted, as in Fig. 6, where the stresses are represented drawn at the ends of their corresponding radii, *i. e.*, the radii normal to the faces upon which the stresses act. This change in the diagram is not at all essential, but is simply a matter of convenience.

We know that *the projection of a vector in any direction is*

equal to the algebraic sum of the projections of its components. The projection of f_1 upon radius r_2, Fig. 6, is

$$f_1 \cos\ (f_1 r_2) = p_1 \cos\ (r_1 r_2)\ +\ q_1\ \sin.\ (r_1 r_2)$$

in which p_1 is the normal component of the stress f_1, and q_1 is its tangential component at right angles to radius r_3. Likewise

$$f_2 \cos\ (f_2 r_1) = p_2 \cos\ (r_2 r_1) + q_2 \sin.\ (r_2 r_1) = p_2 \cos\ (r_1 r_2) - q_2 \sin.\ (r_1 r_2)$$

In the last form it will be noticed that the angle $(r_1 r_2)$ has the opposite sign to that of the angle $(r_2 r_1)$, which involves a change in the sign of the sine but not of the cosine. We may now write Equation 1 in the following form:

$$p_1 \cos\ (r_1 r_2) + q_1 \sin.\ (r_1 r_2) = p_2 \cos\ (r_1 r_2) - q_2 \sin.\ (r_1 r_2).$$

Dividing through by $\cos.\ (r_1 r_2)$ and rearranging we have:

$$p_2 - p_1 = (q_1 + q_2)\ \tan\ (r_1\ r_2) \qquad \text{Eq. 2.}$$

If f_1 is not in the plane of the paper, it will have a normal component p_1 and two tangential components q_1 and q_1'; of which q_1 is in a plane at right angles to radius r_3, *i. e.* the $r_1\ r_2$ plane, while q_1' is parallel to radius r_3 or at right angles to the $r_1\ r_2$ plane. And a similar remark applies to f_2 if it is not in the plane of the paper. Equation 2 is valid for all directions of f_1 and f_2.

Special Case I.—Let our element of volume be right angled throughout, Fig. 7; in Equation 2 the angle $(r_1\ r_2) = 90°$, and its tangent becomes infinite. The equation becomes

$$p_2 - p_1 = (q_1 + q_2) \times \infty.$$

We know that the normal stresses p_1 and p_2 cannot become infinite: so that for this equation to be true we must have

$$q_1 + q_2 = O \qquad \text{or}$$
$$q_1 = -q_2 \qquad \text{Eq. 3.}$$

In words this may be expressed as: *for a right angled element of*

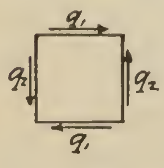


Fig. 7.

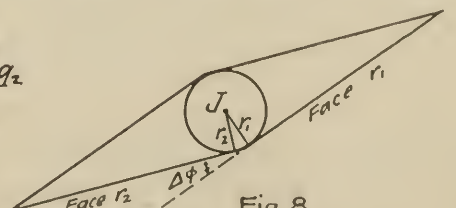


Fig. 8.

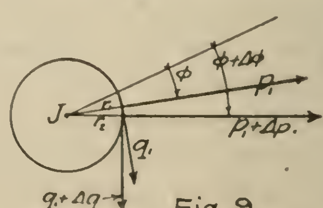


Fig. 9.

volume, the shearing stresses on two adjacent faces are equal in magnitude and opposite in sign.

Special Case II.—Instead of a rectangular element, let us now take one that is very long, as shown in Fig. 8, where the angle be-

tween the radii r_1 and r_2 is very small, $\Delta\phi$. On the face r_1 we have normal stress p_1 and shearing stress q_1, while on face r_2 we may represent the normal component as $p_1 + \Delta p$ and the tangential component as $q_1 + \Delta q$, as shown in Fig. 9. Equation 2 now becomes:

$$p_1 + \Delta p - p_1 = (q_1 + q_1 + \Delta q)\ tan\ \Delta\phi.$$

$$\Delta p = 2\, q_1 \,.\, \Delta\phi$$

$$\frac{dp}{d\phi} = 2\, q_1. \qquad \text{Eq. 4.}$$

As an interpretation of this equation we may say that *the normal stress, p, on a plane revolving about an axis through A, will increase at a rate equal to twice its shearing stress in a direction at right angles to that axis.*

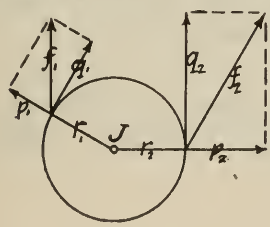


Fig. 10.

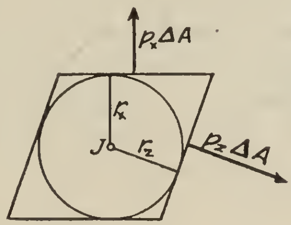


Fig. 11

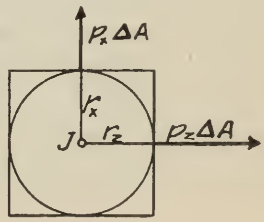


Fig. 12.

Special Case III.—For this case let $(f_1\, r_2) = 90°$, as in Fig. 10. The projection of this stress, then, upon the radius r_2 is zero; and from Equation 1 we know that the stress f_2 must be at right angles to radius r_1, *i. e.*, $(f_2\, r_1) = 90°$. For such conditions, planes r_1 and r_2 are said to be *conjugate*, and their stresses are called conjugate stresses. If we express the above in equations using the components of the stresses, instead of the stresses themelves, just as we did in deriving Equation 2, we have,

$p_1\ cos\ (r_1\, r_2) + q_1\ sin\ (r_1 \cdot r_2) = O,$
and $p_2\ cos\ (r_1\, r_2) - q_2\ sin\ (r_1\, r_2) = O,$
from which we obtain for conjugate stresses

$$\frac{p_1}{q_1} = -\frac{p_2}{q_2} = -\,tan\ (r_1\, r_2) = tan\ (r_2\, r_1) \qquad \text{Eq. 5.}$$

PRINCIPAL STRESSES.

Let us imagine that one has drawn all tangent planes to the sphere about *J*, and he has found that of all these planes face r_x, Fig. 11, has the algebraically least normal stress upon it, and face r_z has the algebraically greatest normal stress. By our well-known criterion for maxima and minima we have, in this case,

$$\frac{dp_x}{d\phi} = O \ \text{ and } \ \frac{dp_z}{d\phi} = O.$$

If we compare these expressions with Equation 4, we see that planes r_x and r_z have no shearing stress upon them; their only stresses are $f_x = p_x$ and $f_z = p_z$, and these stresses are directed along the radii r_x and r_z.

By Equation 2, we have,

$$p_x - p_z = (q_x + q_z) \ tan \ (r_z \ r_x).$$

But q_x and q_z are both zero, while p_x and p_z are finite, hence we must have $tan \ (r_z \ r_x)$ infinite, which shows that the angle $(r_z \ r_x)$ is a right angle, and the planes of Fig. 11 should have been drawn perpendicular to each other, as in Fig. 12.

Let us designate by r_y the radius which is at right angles to the two radii r_x and r_z, thus obtaining again the cubical element of volume. Now since p_x and p_z are at right angles to r_y, the stress f_y is conjugate both to p_x and to p_z, *i. e.*, it is at right angles to radii r_x and r_z, which shows that f_y has no shearing stress in any direction, but consists simply of the normal stress p_y.

The radii r_x, r_y and r_z are called *principal axes*, and the corresponding stresses p_x, p_y, and p_z are called *principal stresses*. Their algebraic magnitudes are indicated by

$$p_x < p_y < p_z,$$

although numerically p_x may be the largest. In our discussion, tensile stress is considered positive; compressive stress negative.

Stress on Any Plane in Terms of the Principal Stresses.—Assume that we know the principal stresses at point J, both in direction and in magnitude. We wish to find the stress f, (components p and q) upon a plane whose radius, r, makes given angles (rr_x), (rr_y) and (rr_z) with the principal axes. Equation 1 gives us the following relations:

$$\begin{aligned} f.\ cos\ (fr_x) &= p_x.\ cos\ (rr_x) \\ f.\ cos\ (fr_y) &= p_y.\ cos\ (rr_y) \qquad \text{Eq. 6.} \\ f.\ cos\ (fr_z) &= p_z.\ cos\ (rr_z) \end{aligned}$$

Squaring these expressions, adding them, and noticing that $cos^2\ (fr_x) + cos^2\ (fr_y) + cos^2\ (fr_z) = 1$, we have

$$f^2 = p_x^2.\ cos^2\ (rr_x) + p_y^2.\ cos^2\ (rr_y) + p_z^2.\ cos^2\ (rr_z) \qquad \text{Eq. 7.}$$

Since the projection of one line upon another line is equal to the sum of the projections of its components, we have the well-known proposition that the cosine of the angle between two lines equals the sum of the products of their projection-cosines, thus,

$$cos\ (r_1\ r_2) = cos\ (r_1\ r_x)\ cos\ (r_2\ r_x) + cos\ (r_1\ r_y)\ cos\ (r_2\ r_y) + cos\ (r_1\ r_z)\ cos\ (r_2\ r_z).$$

Making use of this proposition we have,

$$p = f.\ cos\ (fr) = f.\ cos\ (fr_x)\ cos\ (rr_x) + f.\ cos\ (fr_y)\ cos\ (rr_y) + f.\ cos\ (fr_z)\ cos\ (rr_z).$$

Substituting in this equation from Equation 6, we have

$$p = p_x \cos^2 (rr_x) + p_y \cos^2 (rr_y) + p_z \cos^2 (rr_z) \qquad \text{Eq. 8.}$$

And from the vector relation we know that,

$$q^2 = f^2 - p^2 \qquad \text{Eq. 9.}$$

We have now obtained expressions for the resultant stress, f, its normal component, p, and its tangential component, q, for any plane drawn through point J, these values being expressed in terms of the known principal stresses p_x, p_y and p_z, and of the known angles which locate the plane. Equation 7 represents a closed surface which is symmetrical about each of the principal planes, and whose radii vectores are the resultant stresses, f, drawn from the origin *normal to their planes.* Equation 8 represents a surface drawn in the same way, but whose radii vectores are the normal stresses p.

If these stresses, f, be drawn from the origin in their own directions instead of normal to their planes, they form an ellipsoid; which fact may be shown as follows: Equation 6 may be written thus,

$$\frac{f. \cos (fr_x)}{p_x} = \cos (rr_x).$$

$$\frac{f. \cos (fr_y)}{p_y} = \cos (rr_y).$$

$$\frac{f. \cos (fr_z)}{p_z} = \cos (rr_z).$$

Squaring and adding these expressions, the right member becomes unity and we have,

$$\frac{f^2. \cos^2 (fr_x)}{p_x^2} + \frac{f^2. \cos^2 (fr_y)}{p_y^2} + \frac{f^2. \cos^2 (fr_z)}{p_z^2} = 1 \qquad \text{Eq. 10.}$$

The ordinary equation of an ellipsoid is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1,$$

in which a, b and c are the semi-major axes. If we compare this equation with Equation 10, we see that Equation 10 is the equation of an ellipsoid of which the semi-major axes are p_x, p_y and p_z, and the x, y and z coordinates are $f. \cos (fr_x)$, $f. \cos (fr_y)$ and $f. \cos (fr_z)$, respectively. These expressions are simply the projections of f upon the axes of coordinates, which agrees perfectly with the above interpretation.

November, 1912

Two Dimensional Problem.—In most discussions of this problem it is customary to assume that one principal stress is zero, but this assumption is not necessary. So long as we consider stresses only, without their attendant strains, one principal stress has no effect upon planes which are parallel to the direction of that stress. Let us consider planes parallel to radius r_y, *i. e.* parallel to stress p_y. All these faces are conjugate to face r_y and fall under Special Case III. Since these planes are parallel to stress p_y, their stresses must be parallel to plane r_y, *i. e.* at right angles to radius r_y. This means that none of these faces has any tangential stress parallel to radius r_y; the resultant stress on every such plane lies in the r_x r_z plane, *i. e.* in the plane drawn through radii r_x and r_z.

For this case Equation 8 becomes

$$p = p_x . \cos^2 (rr_x) + p_z . \cos^2 (rr_z).$$
$$= p_x . \sin^2 (rr_z) + p_z . \cos^2 (rr_z).$$
$$= \frac{p_x . \sin^2 (rr_z)}{2} + \frac{p_x (1 - \cos^2 (rr_z))}{2} + \frac{p_z \cos^2 (rr_z)}{2}$$
$$+ \frac{p_z (1 - \sin^2 (rr_z))}{2}$$
$$= \frac{p_z + p_x}{2} + \frac{p_z - p_x}{2} \left[\cos^2 (rr_z) - \sin^2 (rr_z) \right]$$
$$= \frac{p_z + p_x}{2} + \frac{p_z - p_x}{2} \cos 2 (rr_z) \qquad \text{Eq. 11.}$$

If we apply Equation 2 to the conditions assumed above and solve for the shearing stress q, we have

$$q = \frac{p_z - p}{\tan (rr_z)} = \frac{p_z}{\tan (rr_z)} - \frac{p}{\tan (rr_z)}$$

substituting for p the value given in the second equation

$$q = \frac{p_z}{\tan (rr_z)} - \frac{p_z \cos^2 (rr_z)}{\tan (rr_z)} - \frac{p_x . \sin^2 (rr_z)}{\tan (rr_z)}$$
$$q = \frac{p_z [1 - \cos^2 (rr_z)]}{\tan (rr_z)} - \frac{p_x . \sin^2 (rr_z)}{\tan (rr_z)}$$
$$= (p_z - p_x) \sin (rr_z) . \cos (rr_z)$$

$$= \frac{p_z - p_x}{2} \sin 2\,(rr_z). \qquad \text{Eq. 12.}$$

GRAPHICAL CONSTRUCTIONS.

It was pointed out above that the resultant stresses upon all planes drawn through a point, form an ellipsoid if these stresses are plotted as vectors from the same origin, and that the semi-major axes of this ellipsoid are the principal stresses p_x, p_y and p_z. If the principal stress p_y is zero, the ellipsoid evidently degenerates into an ellipse in the r_x, r_z plane and whose semi-major axes are p_x and p_z. If the p_y stress is not zero, but if we are considering only those planes which are parallel to radius r_y, it was pointed out above that all the stresses lie in the r_x, r_z plane, and evidently form the same ellipse as above, *i. e.* a section of the stress ellipsoid made by the r_x, r_z plane.

This construction may be made as illustrated in Fig. 13. From origin *O*, draw p_x and p_z at right angles to each other, and through

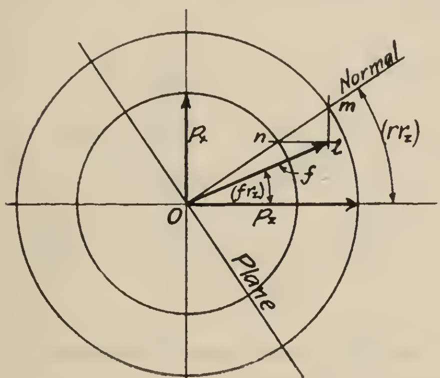


Fig. 13.

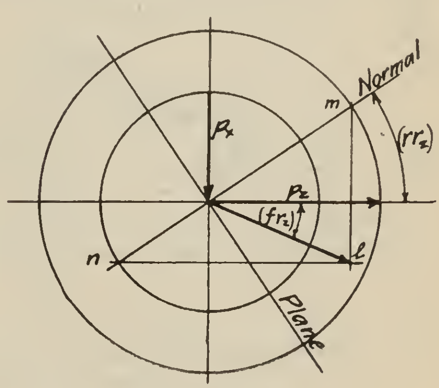


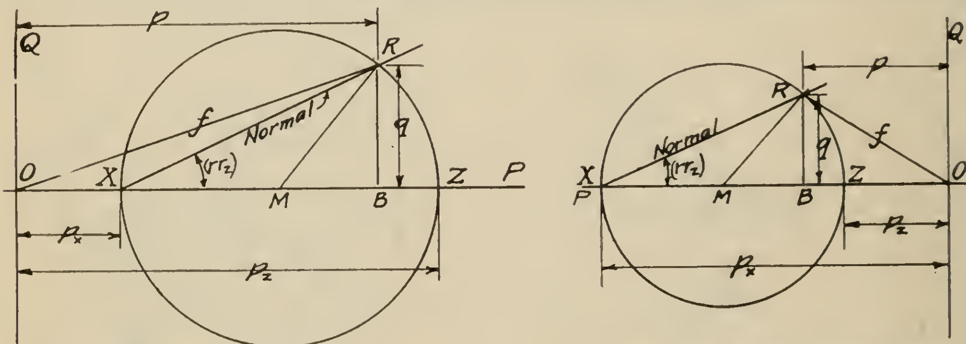
Fig. 14.

their ends draw the circles about *O* as center. Draw the normal to any plane, making the angle (rr_z) with p_z. At the intersections *m* and *n* of this normal with the two circles drop perpendiculars to the axes p_z and p_x respectively; the intersection *l* of these perpendiculars is a point on the ellipse of stress, and the line from *O* to this intersection *l* represents the resultant stress, *f*, on the plane, both in magnitude and in direction. In the above case both principal stresses are tensions, while in Fig. 14 is illustrated the case in which the principal stress p_x is compression. This construction has the excellence that it shows the resultant stress in its right magnitude and direction with respect to the normal and to the principal axes; as a vector picture it is entirely satisfactory; it is, however, not so useful as the circular diagram partially suggested by Rankine and perfected by Mohr. This latter solution is an interpretation of Equations 11 and 12 and is, in fact, an elaboration of the parts of Figs. 13 and 14, which bear the letters *O, l, m,* and *n*.

From *O* as origin, Fig. 15, draw rectangular axes of stress

OP and *OQ*. All normal stresses will be plotted along *OP*, tension to the right and compression to the left, while tangential components or shearing stresses will be plotted parallel to *OQ*, clockwise stresses above *OP*, counterclockwise below. Along *OP* lay off $p_x = OX$ and $p_z = OZ$, and upon *XZ* as diameter draw the circle shown. From *X* draw the normal of the plane upon which the stress is required, making the angle $RXZ = (rr_z)$. The intersection, *R*, of this line with the circle is a point whose coordinates *OB* and *BR*, with respect to the stress axes, are the normal and tangential stresses *p* and *q* required, and the line *OR* is the resultant stress, *f*. This diagram gives the magnitude of these stresses, but the angle *ROP* is the angle (fr) between the resultant stress and the normal, and not the angle (fr_z) as in the ellipse diagram.

In order to justify this construction, one may notice that $OM = \frac{1}{2}(p_z + p_x)$, that $MR = \frac{1}{2}(p_z - p_x)$ and, since the angle $RMB = 2\,(rr_z)$, $MB = \frac{1}{2}(p_z - p_x)\cos 2\,(rr_z)$, and $BR = \frac{1}{2}(p_z - p_x)\sin 2\,(rr_z)$. Now if we compare these expressions for *OB*



Principal Stresses both Tensions. Principal Stresses both Compressions.

CIRCULAR DIAGRAMS OF STRESS

Fig. 15

and *BR* with Equations 11 and 12, we see that $OB = p$, and $BR = q$.

In Fig. 16 we have the three dimensional problem. The principal stresses are p_x, p_y and p_z, the first one being negative, and the normal of the given plane for which the stress is wanted is not in one of the principal planes but makes angles (rr_x), and (rr_z) with the corresponding axes. After the principal stresses p_z, p_y, and p_x have been plotted along the horizontal axis, giving the points *Z*, *Y*, and *X*, three circles are drawn whose diameters are *XY*, *XZ*, and *YZ*. The line *XT* is laid off at an angle $(90° - r_x r)$ with the horizontal, and the line *ZS* at an angle $(90 - rr_z)$. From their intersections *T* and *S* with the *ZX* circle, arcs are drawn using *C* and *D* respectively as centers, and the intersection *R* of these arcs is a point whose coordinates, with respect to the stress axes, are the normal and tangential stresses, *p* and *q*, required, the resultant stress, *f*, being *OR*.

This general graphical solution of the three dimensional problem is interesting, but as such problems are rarely met requiring

solution, it is not thought necessary to give this construction more consideration. One reason for there being little demand for this solution is that the principal planes contain the extremes of stress, *i. e.* maximum tension, compression and shear, and it is to the extreme condition that most attention is given in the design of structures.

EXAMPLES.

In Fig. 17 is shown the circular diagrams for the cases of simple tension, simple compression and simple shear.

Simple tension, Fig. 17 (*a*), occurs in a prismatic specimen

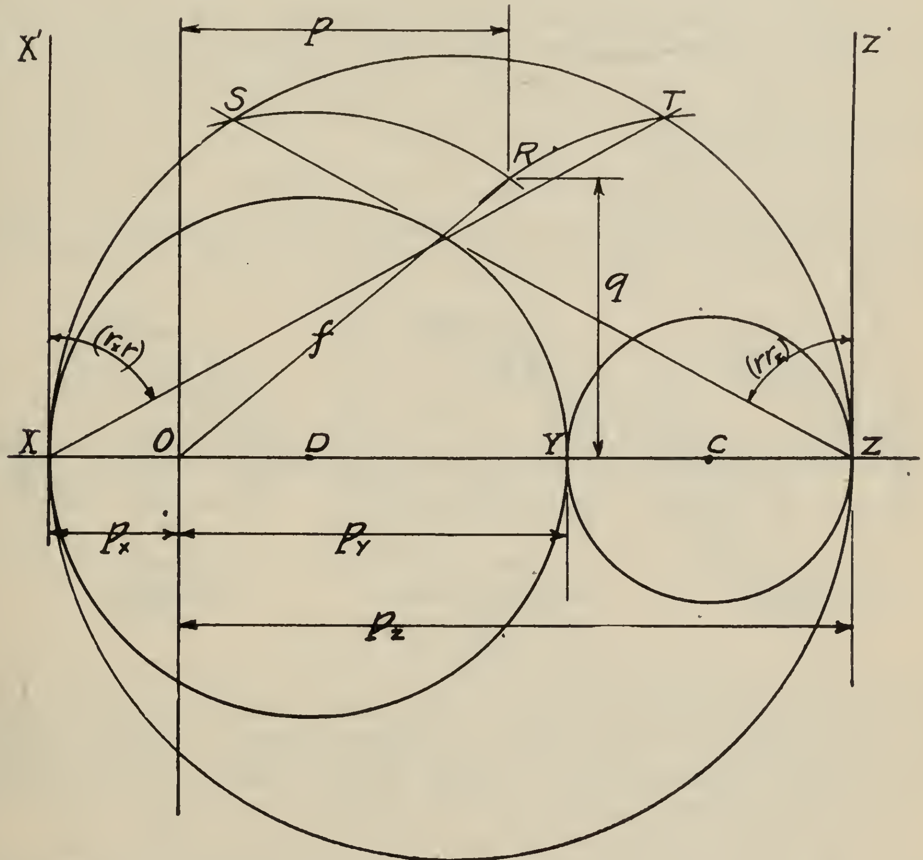


Fig. 16.

under axial tension; it has only one principal stress p_z. The diagram shows that the resultant stress, *f,* on any plane makes the same angle with its normal that the normal makes with the axis of tension. One sees from the diagram,

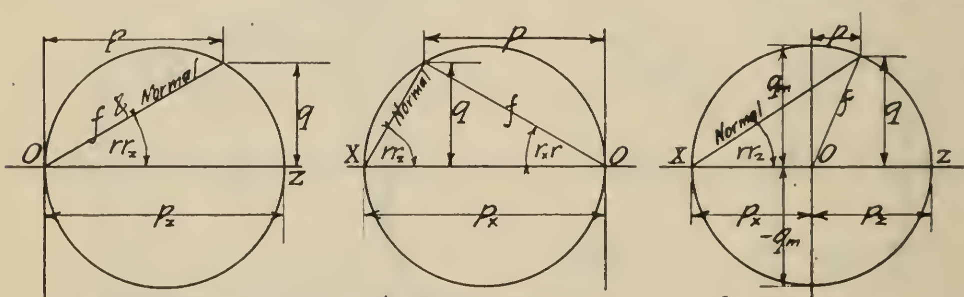
(1) that $f = p_z \cos (rr_z)$;
(2) that $p = f \cos (rr_z) = p_z \cos^2 (rr_z)$;
(3) that $q = f \sin (rr_z) = p_z \sin (rr_z) \cos (rr_z)$;
(4) that the maximum value of q is $\frac{1}{2} p_z$; and

(5) that this is on a plane whose normal makes an angle of 45° with the Z axis.

Simple compression, Fig. 17 (b), occurs in a prismatic speciment under axial compression; its only principal stress is p_x, a compression, here regarded as negative. The above remarks made with respect to simple tension hold with respect to compression if we change the angle (rr_z) to $(r_x r)$.

Simple shear occurs in a cylinder under an axial torque. The pure shearing stresses q_m and $-q_m$, Fig. 17 (c), occur on planes through the axis and at right angles to it. The principal stresses p_z and p_x are tensile and compressive stresses respectively, each numerically equal to q_m, and the principal axes are inclined 45° to the elements of the cylinder. One sees from the figure that the resultant stress, f, on every plane is constant and equal to q_m, that the normal stress is $p = q_m \cos 2 (rr_z)$, and that the shearing stress is $q = q_m . \sin 2 (rr_z)$.

Problem:—To construct the circular diagram of stress, Fig. 18, having given the stresses p_1, q_1 and p_2, q_2, on any two planes. Having drawn the axes of stress OP and OQ, one finds the two



(a) Tension (b) Compression (c) Shear

SIMPLE STRESSES

Fig. 17.

points R and S corresponding to the given stresses. At the point D, at the center of the line RS, a perpendicular is erected, cutting the axis OP in the point C, which is the center of the required circle. The angle between the given planes is the angle RXS.

If the given planes are at right angles to each other, the angle RXS is 90°, and hence the line RS will be a diameter of the stress circle as shown in Fig. 19. One may write down from this diagram the usual formulas for the principal stresses, thus

$$p_z = \tfrac{1}{2}(p_1 + p_2) + \sqrt{\tfrac{1}{4}(p_1 - p_2)^2 + q_1^2}.$$

$$p_x = \tfrac{1}{2}(p_1 + p_2) - \sqrt{\tfrac{1}{4}(p_1 - p_2)^2 + q_1^2}.$$

$$\tan 2 (r_1 r_z) = \frac{2 q_1}{p_1 - p_2} \quad \text{and the}$$

$$\text{maximum shearing stress} = \sqrt{\tfrac{1}{4}(p_1 - p_2)^2 + q_1^2}$$

Similar formulas may be written down from Fig. 18, but they are much more complicated and are rarely needed.

If the two planes are at right angles, and if one of them has no normal stress, the circular diagram is still simpler, taking the form of Fig. 20. This is the very common case used in finding the principal stress in a beam at a section on which there is both bending and shear.

If the principal stresses are of opposite signs, the angle (fr) between the normal and the direction of the resultant stress may have any value between 0° and 180°, but if the principal stresses have the same sign there is a limit to the value of this angle. This is illustrated in Fig. 21. The value of (fr) will be greatest when the line OR is tangent to the circle as shown, in which case,

$(fr)_{max} = sin^{-1}\dfrac{p_z - p_x}{p_z + p_x}$; and it occurs on a plane whose normal makes with the Z axis, the angle $(rr_z) = 45° + \frac{1}{2}\, sin^{-1}\dfrac{p_z - p_x}{p_z + p_x}$

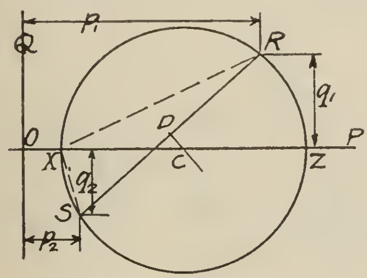


Fig. 18.

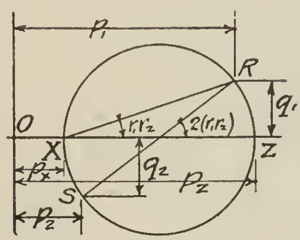


Fig. 19.

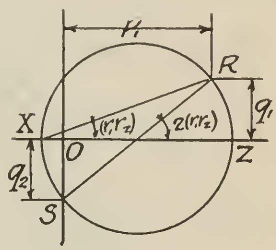


Fig. 20.

If the principal stresses are of opposite signs, the shearing stress axis, OQ, cuts the circle in two points, that represent planes whose stress is wholly tangential or shearing. This is shown in Fig. 22. The normal of the plane in question makes with the Z axis an angle $(rr_z) = 90° - \frac{1}{2}\, cos^{-1}\dfrac{p_z + p_x}{p_z - p_x}$

YIELD STRESSES AND INTERNAL FRICTION.

In finding the mechanical properties of a piece of steel, one generally prepares a prismatic specimen and tests it under axial loads of tension. Sometimes one uses compressive loads, *e. g.* in testing concrete blocks or short cast-iron cylinders, and in some cases the torsional strength is studied by twisting a cylindrical specimen about its axis. In such tests the stresses in the specimen are comparatively simple.

In structures and in machines, the parts are numerous in which

just such simple stresses occur, but there are, in addition, many other cases in which the stresses are not so simple. Most beams carry normal and shearing stresses. The shell of a steam boiler has two unequal tensions, and a rivet is likely to carry large stresses of tension and of shear.

Since materials are frequently used under different conditions than those under which they are tested, it is important that the characteristics, which are determined in the laboratory, shall be so correlated as to enable one to predict the strength of a material under any given set of conditions.

We are familiar with the fact that a short cylinder of cast iron, or other brittle material, when tested in axial compression, fails by shearing along a diagonal plane, Fig. 23, whose normal makes the angle θ with the axis. A 45° plane has the greatest shearing, stress, as may be seen from Fig. 17 (*b*) but the value of the angle θ, as found in actual tests, is always greater than 45°. Navier*[3] was the first to suggest that this lack of agreement between the two angles may be due to friction.

Thus, let k_4 represent the shearing stress which is required to produce a shearing failure in the plane upon which it is applied; let the angle of friction be ϕ; and the coefficient of friction be $f =$

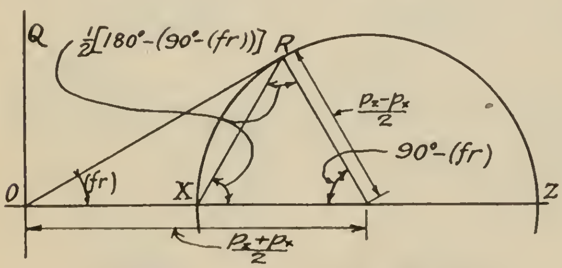


Fig. 21

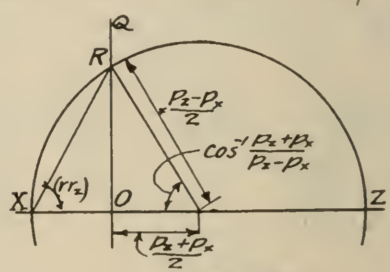


Fig. 22.

tan ϕ. If there is a normal pressure, $-p$, on a certain plane, this pressure will increase the shearing strength of that plane to $q = k_4 - pf = k_4 - p.\ \tan\phi$. In Fig. 24 the shearing strength, k_4, is plotted on the OQ axis, and a line AB is drawn through this point, making the angle ϕ with the horizontal. Any point of the line AB, whose abscissa is p, has the ordinate $q = k_4 - p.\ \tan\phi$. This line AB, therefore, represents all planes upon which failure can occur by slipping, according to the law of friction. This line may be called the *line of slip*.

We may be certain that the stresses represented by the small circle of Fig. 24 will not cause failure, because that circle does not touch the line of slip. In order that failure may result from a given set of stresses, the corresponding stress circle must be tangent to the line of slip. The circle ORX_2 is tangent to the line of slip at R; OX_2 is the compressive strength, which we shall designate by k_2;

*3. Navier's *Résumé des Lecons—1er partie sur la résistance des matériaux* (1833), p. 126. This reference is kindly supplied by Professor Mansfield Merriman.

failure occurs on a plane represented by the point R, and its normal makes the angle $(r_x r) = 45° + \phi/2 = \theta$ with the axis of compression.

The following table of experimental results is taken from Johnson's *Materials of Construction.* The good agreement between the observed and computed angles of rupture furnishes ground for thinking that this friction theory represents the facts rather accurately.

Material.	Observed Angle of Rupture. θ	Observed Angle of Friction. ϕ	Computed Angle of Rupture. $45° + \frac{1}{2}\phi$
"F" Cast Iron	54.8°	20.6°	55.3°
"CW" Cast Iron	55.0°	16.9°	53.4°
Limestone	62.2°	33.4°	61.7°
Asphalt Paving Mixture	59.7°	27.3°	58.6°
Milwaukee Brick	58.2°	27.0°	58.5°

Various*[4] writers have suggested that friction should be considered in correlating the yield stresses of ductile materials such

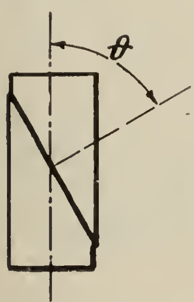


Fig. 23.

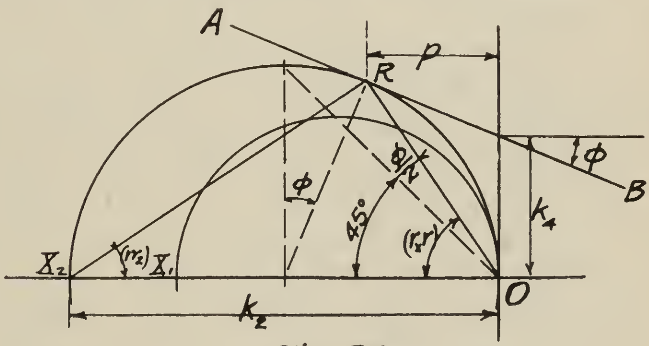


Fig. 24.

as soft or mild steel. The matter has, however, received little attention except from Rejtö,*[5] whose point of view is somewhat different from that here presented. Since 1900 a large amount of work*[6] has been done mainly to show that a ductile material yields at a maximum shearing stress, and none of these writers seems to have paid any attention to the theory of internal friction.

*4—Duguet: Deformation des corps solides, 1885. Mesnager: Congrès International des Méthodes d'Essai, 1900. Mohr: Zeitschrift des Vereins deutscher Ingenieure, 1900. Merriman: Mechanics of Materials, 10th Edn., p. 375.

*5—Rejtö: Innere Reibung der festen Körper, 1897. Tetmajer: Elastizität und Festigkeit, 1904, p. 579.

*6—Guest: Phil. Mag. Series V. Vol. 50, No. 302, 1900. Hancock; Proc. Am. Soc. Testing Materials, 1905, 1906, 1907, 1908. Scoble: Phil Mag., Dec. 1906. Turner: Engineering, Feb. 5, 1909, 1911. Smith: Engineering 1909. Cook & Robertson: Engineering, Dec. 15, 1911.

Ewing and Rosenhain*[7] stretched a piece of soft steel, and at the same time observed with a microscope the changes which took place in its polished surface. They found the yield phenomenon to consist of a series of slips or shears taking place within the crystal grains, one part of a grain sliding a minute distance along the plane separating it from the remainder of the grain. These slips do not all take place in any one plane but, in each grain, follow the natural planes of cleavage. In tests of ductile material, therefore, we must not assume that these slips occur along any one plane, but still there may be some plane whose direction coincides with the average direction of the actual planes of slip, just as, in the kinetic theory of gases, the molecules must have a certain mean speed although the actual speeds are known to include great variations from that mean speed. When the "plane of slip" is referred to in the following, it may be understood as meaning this plane whose direction coincides with the average direction of slip.

When a test is made of steel upon the surface of which there is an oxide film, one of the first evidences of overload is the appearance of diagonal lines in the oxide film. These are called Lüder's*[8] lines from their first observer, and their directions approximate those of the planes of maximum shearing stress.*[9] Their deviation from those directions is generally not less than 2°, and in some cases may be as high as 15° or 20°, and it is to be particularly noted that this deviation is always in the direction which these lines would take if they were traces of planes of slips influenced more or less by internal friction. These lines are certainly not traces of planes of single slips nor parallel slips; the actual phenomenon is much too complicated for such a supposition.

While the internal friction theory cannot be regarded as a complete and final theory, it is interesting, and the circular diagram of stress furnishes easy means of interpreting it. Furthermore the discussion of any theory is likely to lead to the suggestion of improvements. A perfect theory is not born in a day, but is the gradual evolution from the work of many minds. The theory of internal friction, as outlined above for brittle materials, will therefore be applied now to ductile materials taking up simple tension, compression, and shear, followed by combined stresses of tension and shear, compression and shear, and finally coincident principal stresses of tension and compression, obtained in the test of thick cylinders.

We have already discussed the compressive strength of brittle material in terms of the internal friction theory. To make that discussion apply to the elastic strength of ductile material, we have

*7—Phil. Trans. Royal Society of London, A-193-1900-p. 353.

*8—Dingler's Journal, 1860.

*9—Hartmann: Distribution des Deformations, 1896.

but to define k_2, Fig. 24, as the compressive yield stress and k_4 as the yield stress in pure shear.

The diagram for yield stress in simple tension is shown in Fig. 25. Along the vertical OQ the yield stress in pure shear, k_4, is laid off, and through that point the line of slip, AB, is drawn, making the angle ϕ with the horizontal, just as in Fig. 24. The tensile yield stress is obtained by drawing a circle tangent to the line of slip, and whose diameter is OZ along OP. We shall designate this yield stress as k_1. Slipping occurs on a plane represented by the point R; its normal makes with the tensile axis the angle $(rr_z) = 45° - \dfrac{\phi}{2}$. From the two isosceles triangles whose common base is OR, Fig. 25, it may be seen that $k_4 \cos (45° + \dfrac{\phi}{2}) = \frac{1}{2} k_1 \cos (45° - \dfrac{\phi}{2})$, from which we have,

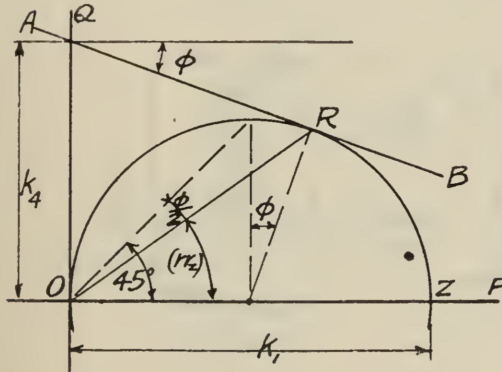


Fig. 25.

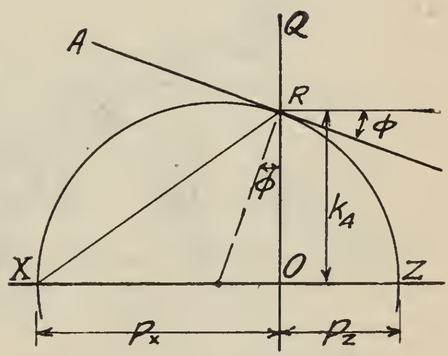


Fig. 26.

$$k_1 = 2\, k_4 \cot \theta \qquad \text{Eq. 13.}$$

the angle θ being defined as in Fig. 23. In a similar manner one may see, from Fig. 24, that $k_4 \cos (45° - \dfrac{\phi}{2}) = \frac{1}{2} k_2 \cos (45° + \dfrac{\phi}{2})$ from which it follows that

$$k_2 = 2\, k_4 \tan \theta = k_1 \tan^2 \theta \qquad \text{Eq. 14.}$$

If we take the angle of friction ϕ, as 15°, the value of θ is 52½° and Equation 14 would make the compressive yield stress about 70% larger than the tensile yield stress; but it is well known that in ordinary tests of steel the compressive yield stress is not much larger than the tensile yield stress. This must be recognized at the beginning as the chief difficulty with this theory.*[10] A part of the

*10—See an interesting suggestion by Mesnager in Congrés International des Méthodes d'Essai, 1900, Vol. 1, p. 160.

discrepancy may be accounted for as due to the difficulty of locating the center of pressure in a compressive test exactly at the axis of the specimen; and this effect of eccentricity is so great that on a ½ in. cylindrical specimen the stress will be doubled by an eccentricity of only $\frac{1}{16}$ in.

By a yield stress in pure shear is meant a wholly tangential stress which causes slipping in its own plane—not in some other plane. This case is illustrated in Fig. 26. Slipping occurs on the plane represented by the point *R*, the point at which the line of slip, *AB*, crosses the axis of shear *OQ;* the stress circle must be tangent to the line of slip at this point. Failure does not occur upon the plane having the greatest shearing stress; the principal stresses are not equal and the principal axes are not inclined 45° with the plane of failure. The magnitudes of these stresses and the directions of their axes are readily written down from the diagram.

A yield stress in simple shear is one in which the specimen is subjected to equal and opposite shearing stresses on planes at right angles to one another, as in the torsion of a cylinder. We shall designate this stress by k_3 and the circular diagram is shown in

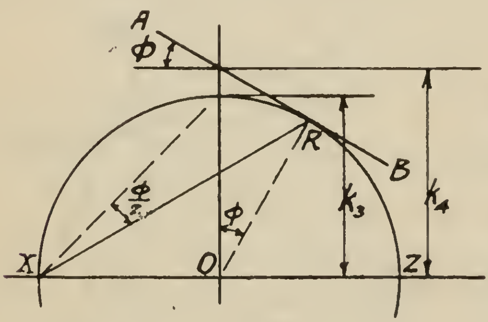


Fig. 27.

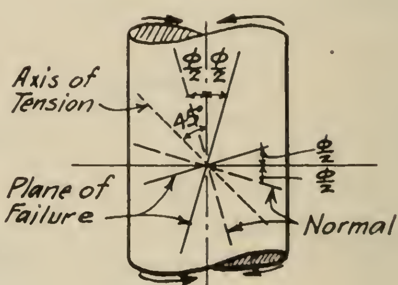


Fig. 28.

Fig. 27. Slipping does not occur on the plane of maximum shear but on a plane represented by the point *R*, whose shearing stress is $q = k_4 \cos^2 \phi$ and whose tensile stress is $p = k_4 \cos \phi \sin \phi$. The normal of the plane of failure makes an angle of $45° - \frac{\phi}{2}$ with the tensile axis. Fig. 28 shows the two planes of failure and their normals for a point on the surface of a cylindrical specimen tested under a right-handed torque whose value has reached the yield point.*11

The torsional yield stress k_3 bears the following relations to k_4 and k_1:

$$k_3 = k_4 \cos \phi = \tfrac{1}{2} k_1 (1 + \sin \phi) \qquad \text{Eq. 15.}$$

An interesting test for student laboratory work is to compare the

*11—Lüder's lines on a cylinder tested in torsion seem always to follow planes either parallel to the axis or at right angles to it.

yield stresses of tension and torsion obtained for the same sample of steel, and thus get a value for the angle of internal friction.

COMBINED STRESSES.

Let us consider the case of tension and shear such as might occur at the edge of a web in an I-beam or a girder. We may assume a rectangular element of volume having only a shearing stress, $-q$, on one set of faces, but on the other set having a tensile stress, p, and a shearing stress, $+q$. If these stresses are such that the element is about to yield on some plane, its stress circle may be taken as the larger one of Fig. 29. The smaller circle of that figure represents a test in simple tension, giving the tensile yield stress k_1 as in Fig. 25. We may now find the relation which p and q must bear to k_1 and k_3 in order that the combination may produce yielding.

The line of slip, AB, is produced until it cuts the axis of normal stress OP at a point distant, k_0, from the origin.*[12]

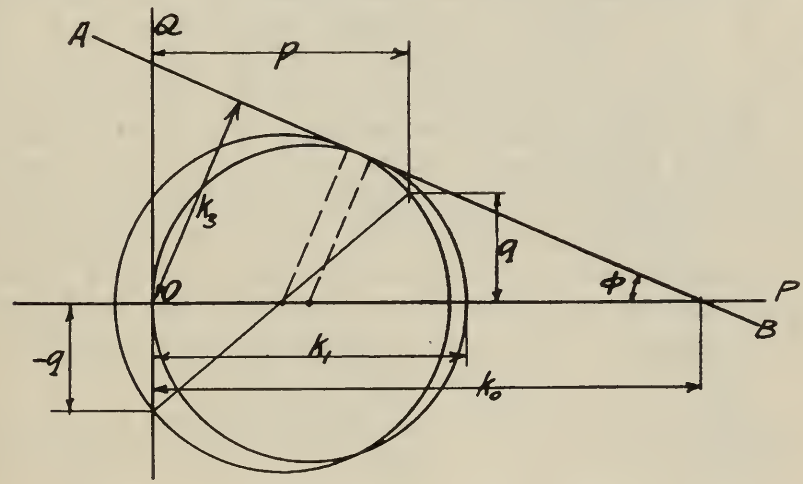


Fig. 29.

Introducing the symbol $\lambda = sin\ \phi$, we have from Fig. 29,

$$k_3 = k_0 \lambda$$

$$k_1 = 2\,k_0 \frac{\lambda}{1 + \lambda}$$

$$k_2 = -\,2\,k_0 \frac{\lambda}{1 - \lambda} \text{ and}$$

$$\left(k_0 - \frac{p}{2}\right) \lambda = \sqrt{\tfrac{1}{4} p^2 + q^2}$$

*12—k_0 represents the stress at which the material would be pulled apart by three equal tensile principal stresses; it may be called the cohesion.

Let us now introduce new variables thus,

$$u = \frac{p}{k_1} \text{ so that } p = 2\, k_0 \frac{\lambda}{1 + \lambda}.\, u$$

$$\text{and } v = \frac{q}{k_3} \text{ so that } q = k_0\, \lambda\, v.$$

After substituting these values in the last equation and solving for v we have

$$v = \sqrt{1 - \frac{2\,\lambda\, u}{1 + \lambda} - \frac{1 - \lambda}{1 + \lambda}\, u^2} \qquad \text{Eq. 16.}$$

This equation has been used in finding the solid curves shown in Fig. 30, which are plotted for two values of ϕ viz., 10° and 20°. If we let $\phi = O$, Equation 16 becomes the equation of a circle of unit radius. This circle is shown as the dot and dash curve of Fig. 30, and represents the requirements of the theory of maximum shearing stress. The points represented in Fig. 30 by small circles refer to tests in tension and torsion collected by Prof. Hancock.*[13] The material was mild or soft steel, but some tests were made with respect to yield points and some with respect to elastic limits.

If we now consider the case of compression and shear on a rectangular element of volume, the normal stress p will be negative, and if we compare it with the compressive yield stress k_2, which is also negative, we may let $w = \frac{p}{k_2}$, and w will be a positive fraction. We may compare the shearing stress q, with the torsional yield stress, k_3, as before, and have $v = \frac{q}{k_3}$. If these values are substituted in the equation

$$(k_0 - \tfrac{1}{2}\, p)\, \lambda = \sqrt{\tfrac{1}{4}\, p^2 + q^2}$$

we find $$v = \sqrt{1 + \frac{2\,\lambda\, w}{1 - \lambda} - \frac{1 + \lambda}{1 - \lambda}\, w^2} \qquad \text{Eq. 17.}$$

The above equation has been used in plotting the dashed curves of Fig. 30. The points indicated by small squares refer to tests in compression and shear. They are too few, however, to give much information. The points in Fig. 30 indicated by small crosses

*13—Proc. Am. Soc. Testing Materials VIII, 1908, p. 375.

refer to tests in which shear is combined with stresses due to bending. They probably belong to the tension shear curves. Large experimental errors seem to be present in many of the results. The diagram as originally drawn, without the friction theory curves, was thought to confirm the theory of maximum shearing stress. The present diagram cannot be said to furnish curves better fitted to the points plotted than the original circle, but it is seen that the curves of the friction theory lie so near the circle that the results apply about as well for them as for the circle. More work of an accurate character is evidently needed.

Experiments upon the strength of thick hollow cylinders tested under internal pressure furnish means of studying combined prin-

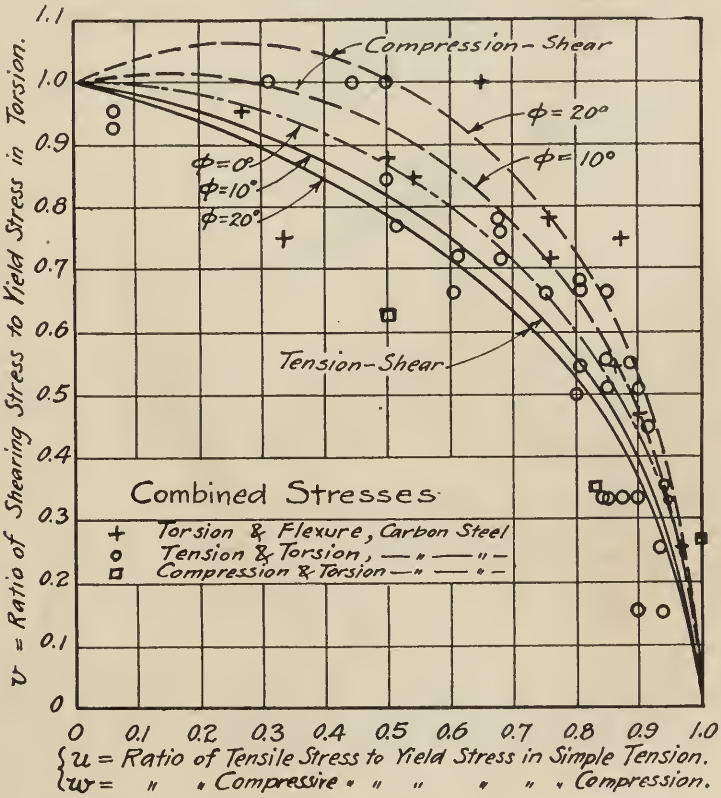


Fig. 30.

cipal stresses of tension and compression, and in this field the theory of internal friction seems to give entirely satisfactory results.

Let the ratio of the external diameter to the internal diameter be denoted by the letter d. Let the internal pressure be p. Assuming now a rectangular element of volume at the internal surface of a cylinder with closed ends, we have the following principal stresses as given by Lamé's theory:

Radial compression $= p_1 = p$, negative,

Circumferential tension $= p_2 = \dfrac{d^2 + 1}{d^2 - 1}\, p$, positive, and

$$\text{Longitudinal tension} = p_3 = -\frac{I}{d^2 - I}\,p, \text{ positive.}$$

Since the third stress is intermediate between the other two, it will not enter into a discussion of the conditions for failure except upon the assumptions of the theory of maximum strain.

If the above stresses, p_1 and p_2, are such as to produce slipping, they may be represented as in Fig. 31. Slipping occurs on a plane represented by the point R, where the larger circle is tangent to the line of slip, AB. The smaller circle represents simple tension at the yield stress k_1. The length of the line MN, Fig. 31, may be expressed, first, as the difference of the radii of the two circles and, second, as the projection of LN on NR, thus,

$$\tfrac{1}{2}(p_2 - p_1) - \tfrac{1}{2}k_1 = [\tfrac{1}{2}k_1 - \tfrac{1}{2}(p_2 + p_1)]\sin\phi.$$

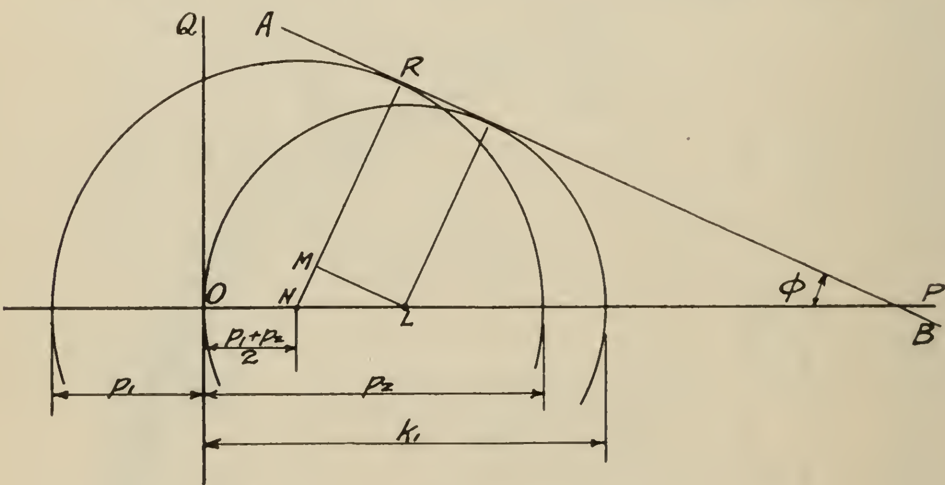


Fig. 31.

If we now substitute the values of p_1 and p_2 given by Lamé's theory, and let $\lambda = \sin\phi$, the above equation gives

$$\frac{p}{k_1} = -\frac{d^2 - I}{2}\cdot\frac{I + \lambda}{d^2 + \lambda} \qquad \text{Eq. 18.}$$

The curve given by this equation is shown in Fig. 32, together with the curve given by each of the three theories*[14] commonly

*14—The equations for the other curves are: Theory of Maximum Principal Stress, $\frac{p}{k_1} = -\frac{d^2 - 1}{d^2 + 1}$. Theory of Maximum Principal Strain, $\frac{p}{k_1} = -\frac{10\,(d^2 - 1)}{13\,d^2 + 4}$. Theory of Maximum Shearing Stress, $\frac{p}{k_1} = -\frac{d^2 - 1}{2\,d^2}$.

recognized. The points on that figure represented by small circles give the results of very careful tests by Cook and Robertson*[15] upon cylinders of annealed mild steel. The agreement of these experiments, with the requirements of the internal friction theory, is in sharp contrast with their lack of agreement with the other theories.

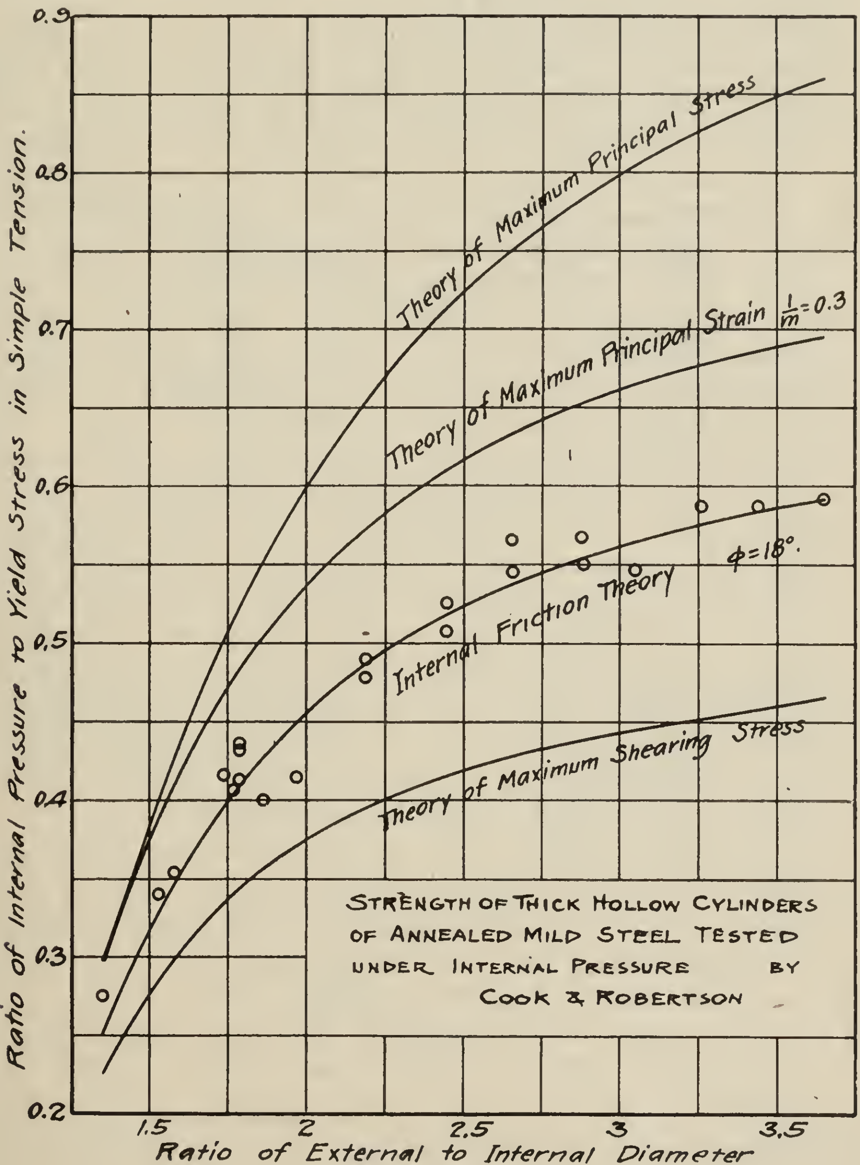


Fig. 32.

EARTH STRESSES.

Let us consider an element of volume at a distance h, measured normally, below the free surface of a bank of uniform material devoid of cohesion. This is shown in Fig. 33 (a), where the

*15—Engineering, Dec. 15, 1911.

free surface is indicated as making an angle, α, with the horizontal. The top of our element of volume is parallel to the free surface; its normal pressure is $p_1 = -w\,h$, in which w is the weight of the material per unit volume, and its shearing stress is $q = -p_1 \tan \alpha$. The ends of the element of volume are shown as vertical and have stresses p_2 and q_2 such that $q_2 = p_2 \tan \alpha$, i. e., the stresses are conjugate. (See Equation 5.)

The assumptions made thus far are not sufficient to determine the stresses. Let us therefore further assume that the material has an angle of internal friction, ϕ, and that the stress, p_2, on the vertical face of the element has its smallest value consistent with stability. The circular diagram of stress is shown in Fig. 33 (b).*[16] The line AB now passes through the origin, O, because there is no cohesion.*[12] The circle is drawn through $p_1\,q_1$, tangent to the line of slip, AB, and its center must, of course, lie on the line OP. The point $p_2\,q_2$ will be on the opposite side of the circle from $p_1\,q_1$, and is further determined by the condition that $q_2/p_2 = \tan\alpha$; the point is below the line OX because q_2 is negative. Failure by slipping is about to occur on planes represented by S and T. These planes are located as shown in Fig. 33 (c); this location is conveniently found by remembering that radius r_2 is horizontal; the radii or normals r_s and r_t are drawn, making the correct angles with the horizontal r_2, after which planes S and T are drawn at right angles to r_s and r_t, respectively. The sense of the slip that may occur upon each of these planes is indicated by arrows in the sketch. The stresses $p_2\,q_2$ are the smallest stresses which the material can present to the vertical face of a retaining wall, provided its coefficient of friction is not smaller than $\tan \alpha$. Rankine's paper, *[17] giving these results by means of an analytical solution, was read before the Royal Society of London, June 19, 1856.

If we were to consider the maximum normal stress on the vertical face of our element instead of its smallest stress, we would have a diagram quite similar to Fig. 33 (b), but p_2 would be larger than p_1 in the same ratio that p_1 is larger than p_2 in Fig. 33 (b).

It is evident that the circular diagram, Fig. 33 (b), can be drawn for all values of the surface slope not larger than the angle of friction ϕ. When $\alpha = \phi$ we have the, so-called, natural slope or angle of repose. The circular diagram for this case is shown in Fig. 34. We see that here $p_2 = p_1$, i. e., the normal stress is the same on the vertical plane and on the plane parallel to the free slope. The shearing stresses are equal in magnitude and opposite in sign on these two planes, and slipping is likely to occur on either of them.

*[16]Diagrams quite similar to this are given in several text-books, *e. g.* Alexander and Thomson's Elementary Applied Mechanics, p. 81.

*17—Transactions Royal Society of London, Vol. 147, p. 9.

Figure 35 (a) is a diagrammatic sketch of a test cylinder*[18] for earthy materials. The dead weight, *W*, rests upon a plug, against the lower end of which the material in the cylinder is pressed by the force *P* acting upon the disc at the end of the cylinder. The force *P*, giving rise to principal stress, p_x, is increased until the plug is raised a minute distance from its seat, thus breaking an electric contact. The weight *W* is overcome by principal stress, p_z. The two principal stresses, p_x and p_z, thus become known and the circular diagram of stress can be drawn for their corresponding values. This has been done in Fig. 35 for fine, dry sand, not sifted, tested in the above manner, the maximum

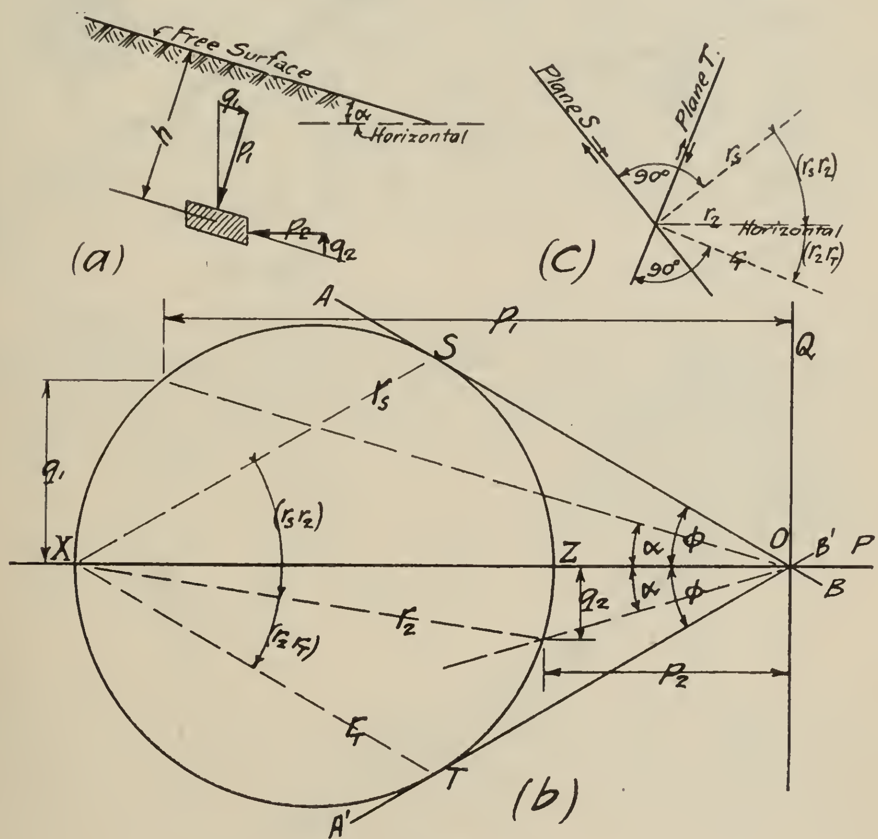


Fig. 33.

value of the pressure in this case being over ten tons per square foot. It will be noticed that the stress circles are practically tangent to the diagonal line shown, and seem to justify the construction. The angle of repose of this sand was tested by allowing it to run through a funnel and form a pile which eventually reached to the spout of the funnel. The maximum angle which the slope reached just before a slide was 33½°, and the angle found just after a slide was 28°. The angle of internal friction found by the

*18—E. P. Goodrich, Trans. Am. Soc. C. E. 53, p. 283, 1904.

cylinder tests was 31°, as shown in Fig. 35, and these values seem to agree well with each other.

Among other results, Goodrich gives the following average values*[19] for a certain kind of bank sand with which he made experiments:

Vertical Pressure, lb. per sq. ft.	2.500	5.000	7.500	10.000
Ratio of Lateral Pressure to Vertical Pressure	0.10	0.18	0.24	0.25

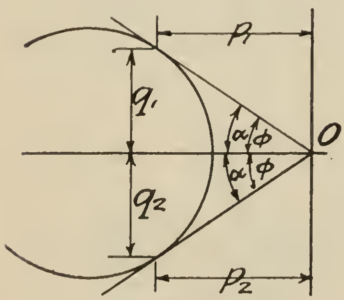


Fig. 34.

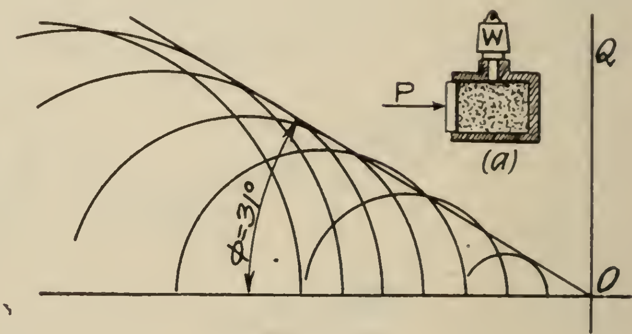


Fig. 35.

These pressures have been plotted as principal stresses in Fig. 36. They give 32° for the angle of internal friction and 800 lb. per sq. ft. for the cohesion.*[12] For the angle of repose of bank sand, Goodrich gives from 31° to 55°, but it is not certain that this

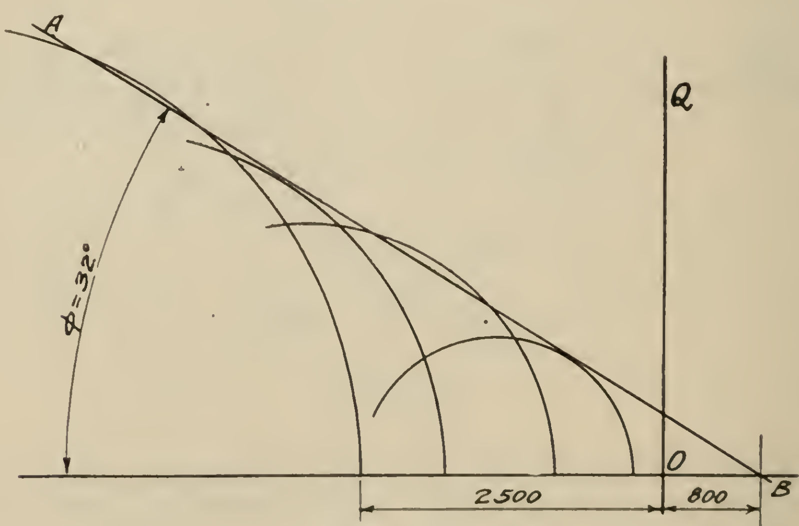


Fig. 36.

refers to the same sand as that described above, though this is highly probable.

In order to find the angle of repose of such material as that

*[19] Trans. Am. Soc. C. E. 53, Dec., 1904, p. 292.

described above, we must assume a certain maximum depth of the bank measured at right angles to the surface; for example, suppose the material weighs 100 lb. per cu. ft. and let the maximum depth at right angles to the surface be 10 ft., giving a normal pressure of 1,000 lb. per sq. ft. on the face parallel to the free surface,—(this face has in addition a large shearing stress). The circular diagram for finding the angle of repose in such a case is given in Fig. 37. This angle is found to be 48°, whereas the angle of internal friction is only 32°. If we had assumed a pile of less depth we should have found a still larger angle of repose, the maximum value being 90° for zero depth. The material is about to slip, both on the vertical plane and on the plane parallel to the free surface, but *this slipping will not occur near the surface,* as in the case of material devoid of cohesion; it will occur at the bottom of the pile, and may not be noticed unless it occasions a large slide.

A mound or bank of such material will take a form resembling that shown in Fig. 38, having steep slopes near the base which

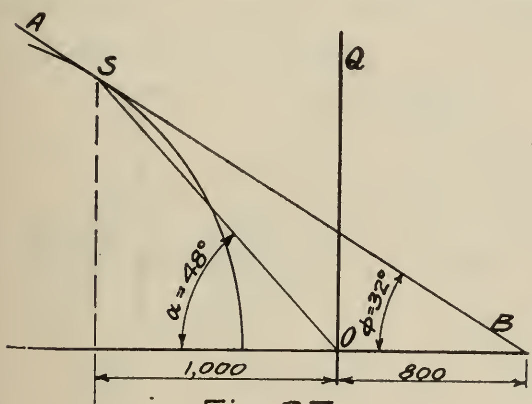


Fig. 37.

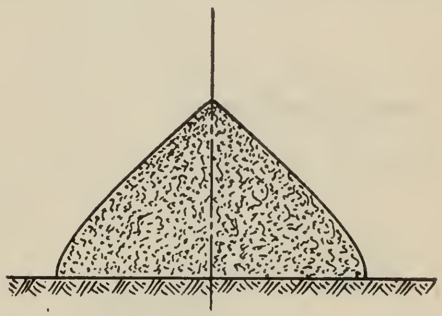


Fig. 38.

flatten down toward the top, the limiting angle being the angle of repose, ϕ, for very great depths. This form is commonly seen for heaps of moist clay and for mortar, but these piles are likely to be much flatter than shown above, due to a smaller angle of internal friction.

In such a bank as that shown in Fig. 38, it will be noticed that slipping is about to occur along the whole base. If the base were sloping downward to the right, the free surface would be steeper on the right side and flatter on the left side. If slipping should occur in such a case it is quite easy to imagine that the whole right half of the bank might detach itself from the remainder and bodily slide down the incline until it reached a base more nearly horizontal. It is quite possible that this may be an approximate explanation of land slides which accompany excavations for canals and the like. The excavation may produce the surface of maximum slope, similar to Fig. 38, and the slide follows either with

further work or simply as a matter of time, for, in many of these phenomena, time enters as a very important factor. In an experience of this kind one cannot be certain that a bank will not slide, unless he knows the form of the underlying base, as well as the physical properties of the material forming the bank.

In digging ditches, it is often found that a bank will stand for some time with a vertical face which will slide later upon an underlying curved surface, somewhat as sketched in Fig. 39. It is probable that the face of the bank yields slightly at first, allowing the weight of the projecting corner to be carried by shearing stresses, which increase the vertical pressure on portions farther from the face. By this readjustment the pressure upon some lower surface becomes distributed somewhat like that indicated by the dotted line in Fig. 39, and when the form of this pressure curve reaches that of the surface of repose, the bank is ready to slide.

The presence of cohesion in a material renders smaller the lateral pressure which is required to insure stability at any given

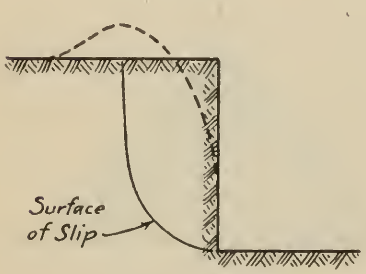


Fig. 39.

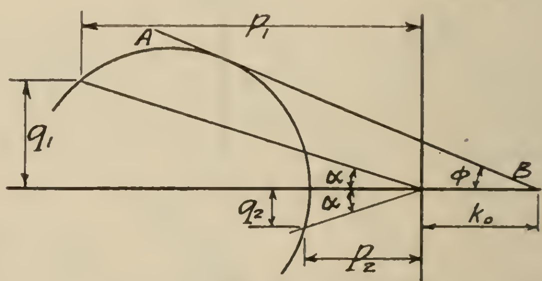


Fig. 40.

point below the free surface. This will be seen by comparing Fig. 40 with Fig. 33. The two figures illustrate the same problem, but in Fig. 33 the material has no cohesion, while in Fig. 40 its value, k_0, is considerable. However, Fig. 40 must not be used in the design of retaining walls without full knowledge of the physical properties of the materials and without due consideration of the question of slides mentioned above. It may be well to call especial attention to the fact that the angle of internal friction cannot be determined from the angle of repose in material which has cohesion.

PILES.

Piles in different localities may be supported in two quite different ways. If a pile is driven, through a soft upper layer, to a firm layer below, the most of its load will be carried by the lower firm stratum and, in this case, the pile acts somewhat like a column. On the other hand, the pile may be driven without reaching any firm bottom, and in this case the pile is supported

largely by friction between its lateral surface and the adjacent earth. Let us consider the pile supported in this second manner.

We may assume that the stresses taken up by the medium from the lateral surface of the pile, are carried off into other parts of the medium as shearing stresses on vertical and horizontal faces of elements of volume. The intensities of these shearing stresses in any horizontal layer will be inversely proportional to their distance from the axis of the pile, being greatest at its surface, which is the only locality whose stresses we need to investigate.

Let us take, near the pile, a rectangular element of volume, as shown in Fig. 41, at a distance, h, below the free surface of a medium having no cohesion. If w be the weight of earth per unit volume, we know that $p_1 = - wh$ and that $q_2 = - q_1$. We wish to find limiting values of p_2 and q_2.

First. Let us assume that the pile is carrying the smallest load, W, which under any possible distribution of lateral pressure can cause additional settlement. The circular diagram for this solution

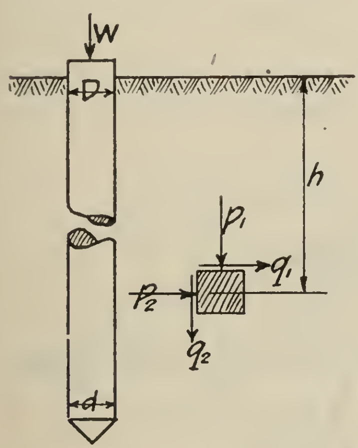


Fig. 41.

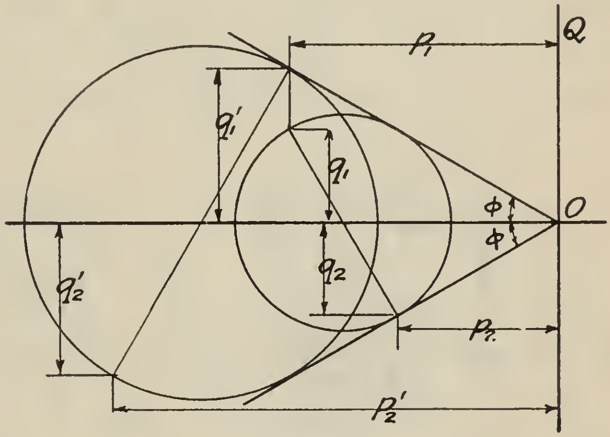


Fig. 42.

is the smaller circle of Fig. 42. It shows that $p_2 = \dfrac{p_1}{1 + 2f^2}$ and

$q_2 = p_2 f = p_1 \dfrac{f}{1 + 2f^2}$. Slipping occurs on the vertical face of the element adjacent to the pile, and of course it is assumed that the coefficient of friction of the surface of the pile is not less than that of the material. If the length of the pile is H, and if its diameters are D, at the top, and d, at the bottom, the minimum load carried by its lateral surface will be

$$W = \tfrac{1}{6}\,(D + 2d)\ \pi\, w\, H^2 \frac{f}{1 + 2f^2} \qquad \text{Eq. 19.}$$

Second. Let us assume that the pile is carrying the maximum load, W^1, which under any possible distribution of lateral pressure is just sufficient to cause additional settlement. The circular diagram for this solution is the larger circle of Fig. 42. The value of p_1 is the same as before, but all the other stresses are larger than before and are marked $q_1{}^1$, $q_2{}^1$ and $p_2{}^1$. Slipping now occurs on the horizontal plane or on its conjugate plane. The diagram shows that $q_2{}^1 = p_1 f$ and

$$W^1 = \tfrac{1}{6}\,(D + 2d)\,\pi w\,H^2 f. \qquad \text{Eq. 20.}$$

If the coefficient of friction of the surface of the pile is smaller than that of the surrounding material, we may designate it by f^1, and in this case f^1 will replace f in Equation 19, but Equation 20 will not be changed unless f^1 is smaller than $\dfrac{f}{1 + 2f^2}$. The circular diagram for the case in which the lateral friction, f^1, is smaller than $\dfrac{f}{1 + 2f^2}$ is shown in Fig. 43, where $f^1 = tan\ \beta$. The expression

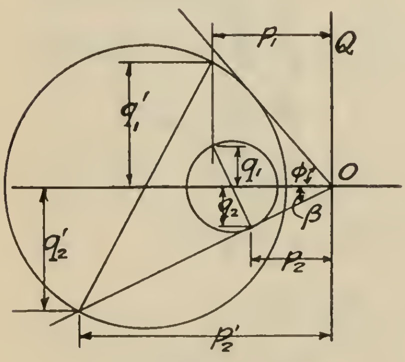


Fig. 43.

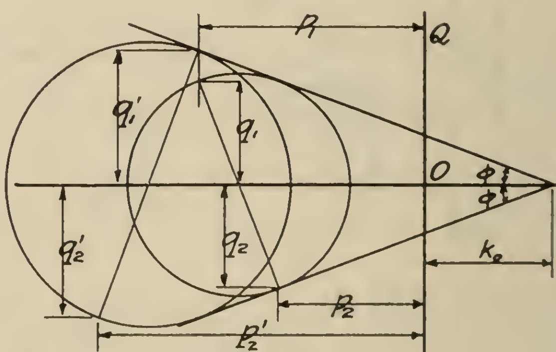


Fig. 44.

for $q^1{}_2$ may be written down from the diagram, but it is too complicated for practical use.

Figure 44 shows the graphical solution for the case of a pile in material whose cohesion, k_0, is not negligible, and the surface of the pile is assumed as having a large angle of friction, especially near the free surface. The diagram shows that

$$q_2 = k_0 f + \frac{p_1 f}{1 + 2f^2 + 2k_0 f^2}$$

and that,

$$q_2{}^1 = k_0 f + p_1\ f.$$

Equations 19 and 20 become,

$$W = \frac{(D + 2d)\,\pi\, w\, H^2 f}{6\,(1 + 2f^2 + 2\,k_0 f^2)} + \tfrac{1}{2}\,(D + d)\; k_0\; f\;\pi\; H. \qquad \text{Eq. 21.}$$

$$W^1 = [\tfrac{1}{3}\, w\, H\, (D + 2\,d) + k_0\;\; (D + d)]\,\frac{\pi f H}{2}. \qquad \text{Eq. 22.}$$

The solution for q_2, given by Fig. 44, will not apply for the lateral surface of the pile near the free surface of the ground, because it assumes too large a value for the angle of friction of the surface of the pile. In Fig. 45 is shown the proper solution for q_2, where this angle of friction is taken as β. In case the angle β is small, Fig. 44 will not give the proper value for $q_2{}^1$ at any part of the pile, for this angle must then be taken into consideration as well as the angle ϕ. The proper solution is shown in Fig. 46.

The value of the load carried by the lower end of the pile may be assumed as

$$\tfrac{1}{4}\;\pi\; d^2\; w\; H^2 \left(\frac{1 + \lambda}{1 - \lambda}\right)^2$$

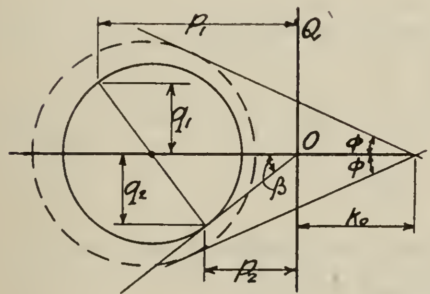


Fig. 45.

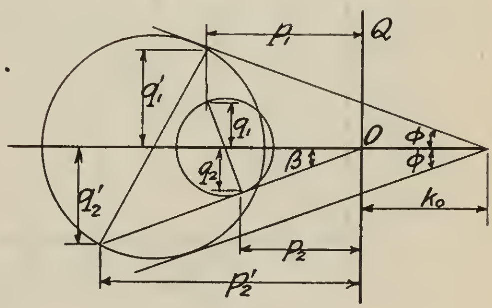


Fig. 46.

We have derived for the pile, a minimum failing load W and a maximum failing load W^1. Let us now find the conditions under which each may be appropriate. When a pile is driven it must push from the space which it is to occupy, all the material previously in that space. As the point advances, the material which was just below it moves downward slightly, but mainly to the side. This horizontal movement of the material compresses the medium in a radial direction. This radial compression is no small stress; the stresses are those required to overcome any resistance which the medium may present. The horizontal stress p_2, will therefore take a maximum value much larger than the vertical stress p_1, and it will continue to remain large unless some opportunity is given the surrounding material to move horizontally with little resistance.

If a tapered pile is driven with its large end downward, it furnishes the opportunity for lateral movement just referred to. The

pile at any section is smaller than the hole made for it by the large point, and allows the adjacent material to settle back toward the pile. In such a case the minimum load W, with appropriate end load, is all that one can be certain that the pile will carry.

If the tapered pile is used with its small end downward, it does not present any opportunity for the relief of the large lateral stresses, and the maximum load, W^1, seems appropriate for such a pile when first driven. In this case, however, the horizontal stress, p_2, may be reduced by excavation near the pile, and we are quite familiar with the slight settlement of the foundations of a building coming at about the time of building operations on adjoining property. This excavation doubtless permits a very small movement of the soil away from the pile, reducing the horizontal stresses, and in consequence the shearing stresses which support the pile. A pile subject to such lateral relief can probably carry a load larger than the minimum load W, but how much larger seems a matter of conjecture.

In order to obtain the largest value for the minimum load, a tapered pile should be driven with its large end downward. If the

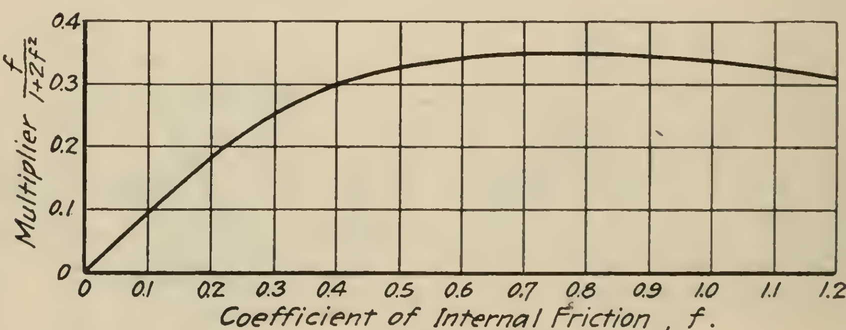


Fig. 47.

value of f is taken as 0.3 in material having no cohesion, and if the small end of the pile has only half the diameter of the large end, the minimum load W, supported by the lateral surface when the large end is down, is larger than the maximum load W^1 for the same pile driven with its small end down. In Equation 19 we may notice that the expression $\frac{1}{6}\ (D + 2d)\,.\,\pi\ w\ H^2$ is simply the total hydrostatic pressure which would be exerted against the sides of the pile if the surrounding medium were a liquid of weight, w, per unit volume. The manner in which the multiplier, $\dfrac{f}{1 + 2f^2}$, in Equation 19, varies with the coefficient of friction, f, is illustrated in Fig. 47. If we take 0.3 as a common value for this multiplier, we may say, roughly, that the lateral surface of a pile may be

depended upon to carry a load equal to 3/10 of the hydrostatic pressure against that surface.

Discussion.

J. H. Griffith (Assoc. Mem. Am. Soc. E. C.):*[20] The writer has never been a firm advocate of detached special graphical or analytic devices for the analysis of stress and strain at a point, and their use in related or similar problems. He believes that such methods as Mueller Breslau's auxiliary circle or Rankine's ellipse of stress, for example, while they may be of great value to those who are votaries of the respective methods, yet they nevertheless detract from the more general point of view, and are far more cumbersome than the usual methods of mechanics. Mohr's method apparently will hardly be classed in this category. Certainly the writer wishes to thank Prof. Basquin for having gone into the matter so thoroughly, having condensed into a small compass a great deal of matter which is only accessible after one has covered a great deal of foreign literature. Aside from all questions of the intrinsic value of the method, which must be subject to some study by American engineers, one of the chief points of interest is the great number of varied problems which have been little studied, that it has brought to the attention of the Society.

The problem as to the conditions under which materials fracture, also the question of internal friction, are among these. The work on internal friction by Prof. Rejtö of Budapest is little known even in Germany, and this, so far as the writer can learn, is largely owing to the former's phraseology. But undoubtedly, as indicated by Professor Basquin, the matter deserves careful attention and investigation. Such experiments as have been made by Guest*[21] in England and Wehage*[22] in Germany deserve to be repeated and carefully studied also.

In the matter of internal friction, the author cites a good method of approach by subjecting the specimen to a pure shear as occurs in torsion, and then to combined shear and normal stresses. The writer hopes to be able to follow this suggestion in the near future in connection with a study of various lime and cement mortars.

Perhaps as good a criticism as any that has been given, covering this whole field, is that by Professor Waldemar Voigt of Goettingen, the distinguished elastician and authority on deportment of crystals under stress. He concludes an extensive discus-

*[20]Bureau of Standards, Pittsburgh.

*[21]See Phil. Magazine, 1900, vol. 48, also "Strength of Materials Under Compound Stress," by Prof. Greene, Mich. Technic, June, 1911.

*[22]Mittheilungen der Mechan. Technischen Versuchsanstalt zu Berlin, 1888.

sion along these lines (Anal. der Physic., Ser. 4, Bd. 4, 1901) as follows:

"According to all appearances we are still remote from the knowledge of the true laws of resistance. Mohr's rule, which may render the greatest service in technical applications, has no general significance whatsoever, and in the simplest cases of homogeneous deformations it may even lead to hopeless contradictions with experience.

"In order to contribute towards an explanation of the obviously highly complicated relations, we need above all more systematic observations under conditions which are prescribed not by technical needs but rather by the scientific point of view. For the present it is advisable to confine ourselves to the simplest conceivable cases, especially to those of homogeneous deformation, and more particularly to bodies which are not considerably and permanently changed before destruction, i. e., those which possess slight ductility. Accordingly, the greatest value should be attached to perfect homogeneity of the products and to the clear definition of the character of their surface."

The point made by Professor Voigt, of the necessity of obtaining data with reference to the purely scientific needs rather than for immediate technical application, is one coming to be more and more recognized by the engineering profession. Many of the observations made a few years ago, for example, are of little value to the present investigators, for the reason that there is often no means of interpreting them in connection with the precise methods which engineering mechanics are coming to prescribe.

Professor Basquin has performed a service in applying his method to the analysis of the pile, which, in spite of much writing, still remains one of the very uncertain problems of engineering, insomuch that the engineers seem to discredit nearly every formula unless it is that of Wellington.

There is need for a great deal of complementary experimental investigation along this line. Engineers are naturally averse to any experiments even suggestive of models, but if these are sufficiently large, say one-fourth actual size, the principle of similarity which is used so extensively in other fields of engineering might with advantage be properly applied in an interpretation of the results. One of the most suggestive fields of research in this connection is that by Mr. George Wilson*[23] which has been little noticed. He sought to find out, taking a rational account of frictions and shears as has Professor Basquin, just what the pulling out force happens to be, and he then studied this in respect to its variation over the periphery of the model. Now the experimental engineer might obtain interesting results on model piles, say six to ten feet long and of various cross sections by pushing them in

*[23]Conjugate Pressures in Sand, Pro. Inst. Engineers, Vol. CXLIX.

or withdrawing them from a tank containing sand, clay, and various other mediums, and which reposed upon a testing machine, to determine just what actual static load may be required. Such a tank should be relatively larger than the diameter of the pile to eliminate the friction effect between the tank and the earth, which would necessarily vitiate results and disturb the frictional action to some extent on surface of pile.

The direct action of friction corresponding to any given depth portion of the original specimen might be found independently by inserting a separate portion, having the same peripheral smoothness as the original, horizontally in the tank, and subjecting this to a lateral force applied through the agency of a wire passing through the earth, and under various degrees of pull. The normal pressure corresponding to the given depth could be applied by means of a loose-fitting piston, there being a few feet of earth between the piston and horizontal piece to be tested.

If the various stress and strain constituents, moduli, etc., which enter into all of these really elastic problems can be furnished, it is largely a matter of mere detail to obtain some sort of a solution, and Professor Basquin's method will doubtless play an important service therein, but heretofore the engineer has largely reversed this procedure. The rule which should invariably be followed is to first obtain the proper data of experience and then interpret these by the principles of mechanics. This has not been done with the result that "theory" is often discredited by those who should be its friends.

November, 1912

THE PRINCIPLES OF MUNICIPAL REFUSE COLLECTION

Samuel A. Greeley.

Presented September 16, 1912.

From the organic life of a community there is produced liquid waste and solid waste. The solid waste is commonly called refuse. In it are included garbage, ashes, rubbish, street sweepings, manure, building refuse, trade refuse, etc. Ordinarily the term refuse is confined to what is more properly house refuse, that is, garbage, ashes and rubbish produced from houses, restaurants, hotels, office buildings, boarding houses, churches, schools, and some small industrial establishments. This paper will deal chiefly with the collection of house refuse, as distinguished from trade refuse, building refuse, stable refuse, and street refuse.

The general subject of refuse removal involves (1) the house treatment, (2) the collection, and (3) the disposal of the refuse. Thus, the collection holds an intermediate position and is subject to the methods of house treatment and disposal. On account of this position, it has an immediate effect on both the other parts of the work.

Of the three divisions of refuse-disposal work, the collection is the most important, for the following reasons:

(1) It is the most costly. Table I shows the cost of collection and disposal, chiefly for garbage, in a number of American cities. From this table it is evident that the cost of collection varies from two to eight times the cost of disposal. The house treatment involves no common cost to the community, but against all householders comes the cost of the house can and its up-keep.

(2) More numerous complaints arise from the failure of the collection service than from the house treatment or the disposal of refuse. At Milwaukee, during my two years' experience as Superintendent of Refuse Disposal, it is significant that only three complaints were received against the disposal system, whereas the complaints against the collection service ranged from five to fifty per day, being more in summer and less in winter.

(3) The collection service affects more people more directly than does the disposal part of the work. An unsanitary point of disposal is generally in an isolated place where it affects but few dwellings and comparatively few people. On the other hand, failure to provide frequent collection service affects directly the people who should receive the service and their neighbors as well. Failure to make collections makes necessary the accumulation of decomposable refuse in the back yard, which may create a nuisance for people living in the same block.

For these reasons, it is unfortunate that the collection of refuse

TABLE I.

REFUSE COLLECTION AND DISPOSAL.

COST OF OPERATION.

City	Year	Material	Cost per Ton — Collection	Cost per Ton — Disposal	Authority.
Albany	(Estimated)	Mixed Refuse	$1.84	$0.41	Wallace Greenalch.
Richmond Borough, New York City	1911	Mixed Refuse	1.64	0.54[1]	J. T. Fetherston.
Seattle	(Estimated)	Mixed Refuse	2.30	0.62	Geo. H. Moore.
Boston	1910	All Refuse	1.41	0.43	Annual Report.
Buffalo	1907	Garbage	2.19		
Chicago	1911	Garbage	3.42	0.38	S. M. Singleton.
Cleveland	1911	Garbage	2.83	—1.04[2]	
Columbus	1911	Garbage	1.88	—0.77[2]	E. W. Stribling.
Milwaukee	1910	Garbage	2.85	0.90	Annual Report.
Minneapolis	1910	Garb. and Ashes	1.32	0.92[3]	Annual Report.
Buffalo	1907	Rubbish	4.90	0.04[4]	Col. F. G. Ward.
		Average	2.42	0.24	

Notes.—1. Estimated from cost per cubic yard.
2. Profit.
3. Cost of garbage disposal only.
4. Cost after deducting profit from rubbish sorting plant.

has not received greater attention from officials connected with the work. During the past ten years a great deal of careful study has been given to the disposal of refuse, but comparatively little has been given to the collection.

We find in use in different cities of this country and Europe a great variety of methods and equipments for refuse collection. It is significant that in Europe, where, on the whole, better collection service is given, more uniform methods are used in the different cities. Almost everywhere large wagons made of steel with fixed covers and holding four to five cubic yards, are in use. The collections are made, generally, at least three times a week, the garbage, ashes and rubbish being collected together in one wagon. They are commonly made at night, and the householder sets the can out on the curb in front of the house in the early evening. It is a common practice there to wash the wagons daily.

On the other hand, in American cities, we find a greater variety. Wagons varying in size, holding from one and one-half to six cubic yards, are used in different cities. These wagons are sometimes covered and sometimes not. The frequency of collection varies from three times a week to as much as once in eight days. It is generally necessary for the collectors to go into the back yard for the cans, and the collections are usually made in the daytime.

Various methods are employed for keeping the wagons clean. This feature is more important in this country than abroad, because it is a common practice in this country to collect the garbage, ashes, and rubbish separately in different wagons. It is a very difficult matter to keep wagons clean in which raw garbage is collected.

These considerations show the importance of making a careful analysis of the collection work.

GENERAL CONDITIONS AFFECTING COLLECTION WORK.

Before proceeding in detail with the elements which particularly relate to the collection service, it is necessary to consider certain general features of the refuse problem which affect the collection in an indirect way. These features may be listed as follows:

(1) The quantity of refuse to be removed.
(2) The quality of refuse to be removed.
(3) The local climate.
(4) The local topography.
(5) The method of disposal.

(1) The quantity of refuse produced depends upon the habits of the people making up the community, and upon the season of the year. In winter more ashes and less garbage are produced than in summer. In poor-class districts there is apt to be more rubbish and less garbage than in rich-class districts. The quantity produced at each house at which a collector stops affects the proper ordering of his work. It is uneconomical for a collector to make the trip

from the back yard to his wagon with only a half can of refuse. Therefore, the interval between collections should be so planned that at each visit the collector will remove one can full of refuse. It is equally uneconomical if the collector finds it necessary to empty two or three cans, because he could make more frequent collections giving better service with the same effort and time spent at the house. On the whole, communities wasting more refuse will have a greater cost for collection than other communities. Abroad, it is estimated that 0.04 cubic feet of refuse are produced per capita per day; for American cities the amount is about 0.10, or two and one-half times as much. Therefore, the collection department in American cities must remove over twice as much refuse as must be removed in European cities.

(2) The quality of refuse is determined by the degree of separation practiced at the house. As already stated, in European cities the various components of house refuse are put into one can at the house. The result is a rather dry material in which the garbage is largely obscured by the ashes and rubbish. In America, as communities grew, garbage was the first waste material to receive attention. It decomposed and made a nuisance more rapidly than ashes or rubbish and, for financial reasons, it was found inadvisable to collect and remove the comparatively unobjectionable ashes and rubbish. Later on, as small cities grew into large ones, it was found necessary to remove the ashes and rubbish. However, because in most American cities large areas of vacant land are generally easily accessible, and because, on account of the great individual wastefulness of the people, a large commercial value is found in garbage, the separate removal of these materials has been continued. This necessitates different kinds of wagons for the different kinds of refuse, and complicates the problem to that extent. In New York, Buffalo, Boston, and Cleveland, three different kinds of wagons are used for the collection of these materials.

(3) The local climate affects the collection service in numerous ways. In cold climates, during winter seasons, garbage does not decompose rapidly and accumulates in smaller quantities, so that the interval between collections can be increased. In southern cities, where it is hot for most of the year, the burden of more frequent collections is necessary. To some extent the climate affects the type of wagon which may be used. Where heavy snows are frequent, hauling becomes difficult, and large wagons cannot be used for continuous service.

(4) The extent of hills and steep grades in cities affects the collection of refuse much as it affects any teaming work. However, it is often possible, by proper routing, to have the wagons make their trip up hill when empty, carrying the full load down the hill. From this point of view, collection work may be easier in a hilly city than in a flat one. The flat city through which there are water

courses presents another difficulty. Frequently the bridges over the waterway are raised above the street grade, and the load which might be carried over the greater part of the way is reduced by the grade necessary in the bridge approaches.

The character of the local pavements also affects the economy of the collection. Teamsters prefer brick or good wood block to asphalt. Poorly paved or unpaved alleys add to the burden of the work.

Table II shows the weights of refuse which can be hauled up different grades over good pavements:

TABLE II.

(Data from I. B. Potter.)

Grade Feet per 100	Net load, one horse
0	4,000
1.0	3,600
2.0	3,240
2.4	2,880
3.3	2,540
4.0	2,000
5.0	1,600

(5) The local conditions frequently determine the method of disposal of the refuse. In small cities of less than 100,000 people, it is not generally economical to dispose of garbage by reduction, and local conditions will determine whether it is to be buried in the soil, delivered to farmers as feed for pigs, or burned. If it is used for feed, it must be collected very frequently to insure its freshness, and must be kept entirely free from rubbish and ashes. If it is burned, it should preferably be mixed with ashes and rubbish, and in any event should be kept as dry as possible.

In the larger cities of this country, a reduction method of disposal for garbage has been found advantageous. This requires a separate collection of the garbage. Ashes may always, with proper care, be removed to dumps. In some cities, notably Buffalo, it has been found profitable to sort out the salable portions of the rubbish. This makes it necessary to collect the rubbish separately from the other materials. Therefore, the method of disposal may, in a general way, force certain methods of collection.

SPECIAL FACTORS IN THE COLLECTION SERVICE.

Coming now to a more detailed analysis of the collection service, there are a number of features which influence this work. These may be listed as follows:

(1) The frequency of collection.
(2) The time required to collect from each house.
(3) The working time of the collector.
(4) The length of haul.
(5) The quantity of refuse.

(1) As already indicated, the frequency of collection is one

factor which determines the amount of refuse to be collected at each house. The interval between collections should be determined,—*first,* to prevent nuisance; *second,* to satisfy the householder, and, *third,* to give opportunity for at least one full can of refuse to accumulate. These factors have different effects at different seasons of the year. In winter ashes accumulate more rapidly and require more frequent removal than in summer. Garbage, on the other hand, does not accumulate and does not decompose so rapidly, for both of which reasons the interval between collections may be increased. In the summer it is my observation that garbage should be collected at intervals of two days. Ashes should be collected at least twice monthly, even in summer. In Milwaukee, during the summer of 1911, an attempt was made to collect no ashes from residences from June 15th to September 15th. It was found necessary, however, to make a collection during July because of the very many complaints received. The accumulation of rubbish is fairly constant throughout the year, being somewhat greater in the springtime during the cleaning up and moving season.

Industrial or steam ashes should be collected at the expense of the producer. In Milwaukee such ashes were removed by city teams at a cost of $1.50 per load, paid by the producer. The interval between collections should be from about seven to three days, depending upon the storing and handling facilities at the premises.

Mixed refuse does not decompose as rapidly as garbage but accumulates more rapidly. In European cities mixed refuse is collected from six to three times a week.

Table III gives the frequency of collection practiced in several cities here and abroad.

TABLE III.

Frequency of Collection.

"Paris and Cologne, mixed refuse collected daily; Bremen, Hamburg, Essen and Frankfort, mixed refuse collected three times a week; Rochester, garbage collected daily (except Sundays) in the central portion of the city, from May 15th to October 15th, and three times a week in the remaining part of the city. From October 15th to May 15th, twice a week in the first section of the city, and once a week in the remainder of the city. Ashes and rubbish are collected together weekly through the fall, winter and spring, and semi-weekly in summer; Columbus, garbage collected weekly from November to May, and twice a week from May to November. Garbage and rubbish are collected daily from hotels and restaurants. Ashes and rubbish are collected once every ten days; Milwaukee, garbage collection varies from daily for hotels and restaurants to weekly for residences throughout the year. Ashes and rubbish are collected about twice a month; Minneapolis, garbage, ashes and rubbish are collected weekly, except from hotels and restaurants, where the collection is more frequent. The garbage is all wrapped in paper to prevent its decomposition; Buffalo, garbage, ashes and rubbish are collected daily all the year from the business section of the town. For the remainder of the town, they are collected twice a week from May to November, and once a week from November to May; Philadelphia, garbage is removed six times a week from all buildings; Denver, garbage collected once a week in winter, and three times a week in summer."

(2) The time required to collect from each house has a most important bearing upon the economy of the collection service. In Milwaukee, during the spring of 1911, a very complete record was kept of the work done by the collectors. Observations were made of twenty-one collectors and data secured showing the length of time spent by the collector in harnessing his horse, going to the point of collection, collecting from the required number of places, and carrying the full load to the point of disposal. These data are summarized in Table IV. The records are given for each wagon making one trip. The wagons made, generally two, but sometimes three trips, per day. The districts were assigned to the drivers as to length of haul and difficulty of collection, so that two loads would approximate an 8-hour day.

TABLE IV.

MILWAUKEE DATA.

Detailed Analysis of Collectors' Work.

Number of blocks covered on one trip.	Number of places entered.	Time in Minutes per Trip: Total.	Hauling.	Collecting.	Per cent of total time spent collecting.	Ave. time in mts. to clean one place.
3	58	305	225	80	39%	1.38
5	49	227	167	60	26%	1.22
2	32	249	174	75	30%	2.34
2	45	108	60	48	44%	1.07
3	39	220	150	70	32%	1.79
4	45	216	88	128	59%	2.85
4	24	225	110	115	51%	4.80
8	106	233	100	133	57%	1.25
4	38	316	210	106	34%	2.79
2	15	170	100	70	41%	4.67
6	8	121	66	55	45%	6.87
4	9	80	36	44	55%	4.90
1	6	124	92	32	26%	5.33
3	58	175	119	56	32%	.97
4	15	200	136	64	32%	12.80
6	18	180	75	105	58%	5.85
5	90	300	115	185	62%	2.06
3	59	244	89	155	64%	2.63
1	26	266	151	115	43%	4.43
5	13	205	120	85	41%	6.54
6	45	150	50	100	67%	2.22
6	32	250	160	90	36%	2.81
Average					45%	3.18 minutes

These observations were made in April, 1911. Districts were chosen in different sections of the city to cover different conditions of service, ranging from small house to hotel districts as indicated by the number of places entered.

The most striking feature of the table relates to the number of places which one collector can visit in one day, and the length of time required at each house or stopping place. It was found on the average that one collector could enter from fifty to one hundred

houses in an eight-hour day, and that the time consumed in cleaning one house was slightly over three minutes. Very little data of this nature are available. However, in a book entitled "Cleansing," by Arthur May, Cleansing Superintendent of London, it is stated, on page 116, that: "It has been generally accepted that, with a shoot within two miles of the dusting district, a one-horse van with a capacity of four cubic yards would, under normal conditions, make from 240 to 250 calls and collections each day of ten hours; . . . In districts where dust bins (house cans) are placed on the edge of the curb . . . it is quite possible to make as many as 500 collections in one day."

Comparing this with the Milwaukee data, it appears that the London collector is able to enter from three to five times as many houses per day as can the Milwaukee collector. Presumably, therefore, the work in London can be done by from one-half to one-third as many men per unit quantity of refuse. Mr. May states further in his book that, "a large city like Manchester has over seven million weekly emptyings every year; and one minute's delay in each emptying mounts up in the year to a loss of 116,666 working hours for horse and cart and one or two men."

This quotation gives the meat of the situation. It is the location of the can which chiefly determines the speed with which collectors can clean each house. Where the can is placed by the householder on the curb, as in Hamburg, Paris, London, and other European cities, it requires but a few seconds for the collector to empty the can into his wagon. The careful field investigation in Milwaukee shows that it requires over three minutes to perform the same operation, where the can is kept in the back yard or cellar.

(3) The working time of a collector may be divided into the productive time, or the time actually spent in collecting and emptying the house cans into the wagon, and the unproductive time, or the time spent driving the loaded wagon from the last point of collection to the point of disposal. Evidently the unproductive time should be kept as low as possible. To do this, the wagon should be as large as possible in order that the least number of trips to the point of disposal should be made. If it were possible to handle a wagon so large that the time required to load it would leave only sufficient time to make one trip to the point of disposal, then the most economical operation of the wagons would result. It is of interest to know, in this connection, that the city of New York is experimenting with a nine-yard wagon for hauling garbage and ashes. The present garbage wagons hold one and one-half yards, and the ash wagons three yards. It is, therefore, a striking departure from their past experience. Mr. Edward D. Very speaks very enthusiastically of the expected economies, and there is no doubt that he is proceeding along the right lines.

In the Milwaukee field investigation, as set forth in Table IV,

the average time which a collector making two trips a day spent in the productive work of collecting, was only 45% of the working day. It is well worth serious effort to raise the productive time above this figure.

(4) The length of haul has a similar effect upon the collection service. If all of the refuse has to be transported to one point of disposal, the length of haul will be about halved if two points of disposal are available. Elements of this sort frequently determine the most suitable method of disposal, and show the vital relation which exists between the collection and disposal of refuse. For example, in Milwaukee the most available site for a reduction plant was at Mequon, about seven miles north of the city. On the other hand, a very central location was available for an incinerator, with suitable locations for other plants available for future development. On this account, the cost analysis showed the incineration of mixed refuse to be cheaper than the reduction of garbage, the burning of rubbish, and the dumping of ashes, the balance in favor of the former method being due chiefly to the shorter length of haul.

In a city of 100,000 people, producing say 50 tons of garbage per day, a change in the length of haul sufficient to increase the cost of collection by 20c per ton is equivalent to a capital sum of about $60,000. This sum will considerably more than make up the difference in the cost of building two smaller disposal-stations properly located, instead of one large plant.

The length of haul can frequently be reduced for the wagon service by having loading-stations, from which the refuse is taken by train, boat, motor, or trolley to the point of final disposal. In Cleveland, Columbus, and Minneapolis, garbage is taken from a central loading-station on freight trains, to the point of final disposal, several miles outside of the city. In Philadelphia and Brooklyn, trolley cars are used for this service. In Chicago, Frankfort, and New York, transportation by water is used. Recent improvements proposed for handling refuse in Boston include the installation of large motor-trucks for the major portion of the haul. The difficulty of keeping centrally located loading-stations clean should be emphasized. They serve to shorten the wagon haul and therefore help in reducing the unproductive time of the collector.

(5) The quantity of refuse produced by the people varies in different communities, and in different parts of the same community. If small quantities of refuse are produced per capita, the collector, on a given frequency of collection, will find a smaller accumulation in the house can, and his work will be correspondingly handicapped. If large quantities are produced per capita, a wagon of given size will not serve as large a portion of the population. This feature is particularly evident when comparisons are made between refuse collection in European cities and American cities. In Europe the per capita production of garbage, ashes, and rub-

bish together amounts to about 0.04 cubic feet per day. The figure for American cities is generally above 0.10, or about two and one-half times as much as the European figure. Evidently, therefore, the collection service abroad should be rendered more economically than in this country. An analysis of the collection service under the two conditions bears out this conclusion. It has been found that for European conditions the mixed house-refuse of 100,000 people can be removed by about fifteen wagons. In American cities it is found that about thirty wagons are required. Although these figures cannot be taken in too literal a way, they serve to show that the quantity of refuse produced by each locality must be considered in an analysis of the collection work.

The special factors in the collection service have thus been listed and discussed.

The relative effect of these special factors upon the collection service can best be seen by grouping them into expressions. This has been done as follows:

FACTORS.

W = number of collection wagons.
V = capacity of one wagon in cubic feet.
F = interval between collections in days.
T = time required to collect from one house expressed as parts of an hour.
C = the percentage of working time spent by the collectors in the actual time of collecting as distinguished from hauling to and from the point of disposal.
D = length of working day in hours.
S = number of trips to point of disposal per wagon per day.
P = total population.
N = average number of people per house.
R = the daily quantity of refuse per capita—cubic feet.
g = the daily quantity of garbage per capita—cubic feet.
d = daily quantity of ashes per capita—cubic feet.
r = daily quantity of rubbish per capita—cubic feet.

Equation I. $$S = \frac{D \times C}{T} \times F \times N \times R \times \frac{1}{V}$$

Equation II. $$W = \frac{P \times R}{S \times V}$$

Equation I shows the number of trips to the point of disposal per wagon per day in terms of the productive working time. the time required to clean one house, the frequency of collection, the per capita production of refuse, and the capacity of each wagon. It shows that the number of trips per day will increase with the productive working time and the per capita production of refuse; but will decrease as the time required to clean one house increases, and the size of the wagons becomes larger. Equation II shows the total number of wagons required in terms of the total amount of refuse produced, the number of trips per wagon per day, and the capacity of each wagon. The number of wagons required will be greater for greater quantities of refuse, and will be less for

larger wagons making the same number of trips per day to the point of disposal. The total number and capacity of wagons required is a good index of the cost of the service, for it also determines the number of workmen and horses employed. These two expressions serve to bring out the relative importance of the various factors in the collection service. They are by no means set forth as definite formulæ. Their use is wholly analytical. It

APPLICATIONS

City	Population	actual number of wagons in service	capacity of wagons in cubic yds.	Interval between collections in days	assumed time spent collecting	assumed time required per house	Number of trips per wagon per day	number of wagons per 100,000 population actual	computed
			$\frac{V}{27}$	F	C	T	S	W	
EUROPEAN CITIES—MIXED COLLECTION.									
HAMBURG	1,000,000	90	5.0	2	0.75	$\frac{1}{90}$	2.41	9	12
FRANKFORT	920,000	60	2.5	2.5	0.65	$\frac{1}{60}$	3.47	14	17
AMERICAN CITIES — SEPARATE COLLECTION.									
GARBAGE:—									
MILWAUKEE	375,000	95	1.5	8.0	0.45	$\frac{1}{20}$	2.14	25	23
COLUMBUS	181,000	20	2.5	4.5	0.65	$\frac{1}{40}$	2.08	11	14
ROCHESTER	225,000	30	3.3	3.0	0.70	$\frac{1}{60}$	1.68	13	13
ASHES & RUBBISH:—									
COLUMBUS	181,000	40	3.5	10.0	0.50	$\frac{1}{20}$	5.92	22	22
ROCHESTER	225,000	50	4.0	6.0	0.60	$\frac{1}{25}$	4.67	22	24

ASSUMPTIONS:—	
D	= 8.0 hours.
R	= 0.04 cubic feet for European Cities.
g	= 0.02 " " " American "
a	= 0.07 " " " " "
r	= 0.05 " " " " "

is frequently easy for a cleansing superintendent to determine how much time his collectors are spending unproductively in going to and from the dumps. He should, also, be able to determine quite accurately the frequency of collection, the total refuse, the capacity of the wagons and the average number of trips made per wagon per day. With these data in hand he can estimate from Equation I

the time required to collect from one house. If this is excessive, he may find it advisable to secure better co-operation betwen the collectors and the householders. In Milwaukee it was expected to secure this co-operation by employing, for a year or two, one or more inspectors whose work should be the correlation of the house treatment and collection service. The application of these two expressions to a few typical cities of Europe and America is shown above.

CHOICE OF EQUIPMENT.

Based on the foregoing detailed analysis of the various elements which affect the efficiency of the collection service, it is next proper to consider the choice of the equipment for any particular locality. In this case, also, the choice of the wagon is the chief question, the particular elements affecting the choice of wagon being as follows:

(1) Its size.
(2) The ease of loading the wagon.
(3) The ease of cleaning the wagon.
(4) Its manipulation.
(5) The covering of the wagon.
(6) The dumping of the wagon.
(7) The method of transportation.

(1) Theoretically, a wagon should be so large that the time required to fill it would leave sufficient time out of a working day for only one trip to the point of disposal. In this way the unproductive time in traveling to and from the dump would be reduced to a minimum. Examples of the effect of this feature on the economy of the collection service have been given. A large wagon requires and gets a more intelligent collector than a small wagon.

(2) The work required to load the wagon has a considerable effect on the final cost of the collection service. The loading height should be such that the workmen going with the wagon can easily turn the contents of the can into the wagon. If only one man goes with the wagon, the height should not be over six feet, but should preferably be nearer five feet. If a stepping board placed at the rear and on the sides between the wheels is used, two men can load a somewhat higher wagon. This general statement does not apply with such force for rubbish wagons. Rubbish is a lighter material and is cleaner to handle, so that the collector can pile it to a considerable height in his wagon. Rubbish wagons in Buffalo and New York are loaded to a height of more than 8 ft. Figure 1 shows a new type of wagon designed for collecting garbage in Milwaukee. The wagon is set very low to facilitate loading, and at the same time the capacity of the wagon is kept up to 4 cu. yds. Fig. 2 shows a new type of wagon recently installed on an experimental basis in New York City. The wagon has a loading height of less than 6 ft. with a capacity of 9 cu. yds.

(3) The first essential for efficiency in the collection service is that the wagons should be kept clean. This is particularly true with the separate collection of garbage. It is the common practice

Fig. 1. New Type of Garbage Wagon—Milwaukee.

abroad, where mixed refuse is collected, to wash the wagons with a hose after each day's work. In Milwaukee two washings a week with a hose and broom were not sufficient to prevent the wagons

Fig. 2. New Type of Garbage Wagon—New York.

from creating a nuisance in hot weather. In Buffalo an attempt was made, with fair success, to disinfect the wagons. In Chicago the disinfection of the wagons has not been effectively carried

out. In general it may be said that the wagons in which raw garbage is hauled, should be washed daily in summer.

The odor from garbage comes from its decomposition, and it

Fig. 3. Garbage Cart—Staten Island, N. Y.

Fig. 4. German Wagon—Fixed Cover and Doors.

is chiefly the leavings in the wagon which make the trouble. Hinged covers are objectionable on this account, a fixed, or canvas, cover being kept clean more easily.

(4) The question of handling the wagon over rough roads and in narrow alleys where short turns are required, will have some effect on the choice. In the attempt to increase the capacity of the wagon, a long wheel base is desirable. This, however, has a tendency to make the wagon clumsy. In many places it will be necessary to have small carts for work in alleys and other inaccessible places.

(5) Wagons require covering for several reasons, depending upon the service. Those used for collecting ashes or rubbish and sometimes mixed refuse, should be covered to prevent dust and loose paper from blowing away into the street. This is a frequent complaint. I know of one city in Germany where the Cleansing

Fig. 5. Chicago Garbage Wagon.

Superintendent told me that he had found it necessary to make his collections at night, because of the dust nuisance from emptying the cans into the wagon. Garbage wagons should be covered to prevent nuisance to both sight and smell. Figure 3 shows a garbage cart used in Staten Island, New York, covered with canvas cloth. Figure 4 shows a wagon in use in Germany, with a fixed cover, fitted with doors. Figure 5 shows a garbage wagon in Chicago, with loosely-hinged covers. Similar wagons are used in Cleveland and Milwaukee. Figure 6 shows a 100 cu. ft. garbage wagon in Minneapolis, full of garbage wrapped in paper as collected from the houses, and Figure 7 shows the wagon with the canvas cover in place. It is my observation that wagon covers fitted with doors are more durable, less noisy, and more easily kept clean than the

others. With careful supervision and operation, the canvas cover has the advantage of cheapness and simplicity. It is, however, susceptible to neglect.

(6) A loaded wagon must be dumped with as little loss of time as possible. The method of dumping depends partly upon the final method of disposal. Where the refuse is taken to dumps, bottom-dumping wagons are the most serviceable. Four yard bottom-dumping wagons were tried in Milwaukee for the collection of garbage, but it was impossible to keep them water tight, so that in wet weather their use was objectionable. For ashes and rubbish they have proven very satisfactory. The distance from the

Fig. 6. Minneapolis Wagon—Garbage Wrapped in Paper.

ground to the bottom of the wagon is limited to a certain fixed maximum, sufficient to give clearance to the bottoms when open, and this reduces the available capacity. Many wagons used in the collection service are set on hinges from the rear axle, and are dumped by raising the forward end. This is a common method abroad. It allows a large wagon which can be dumped anywhere with reasonable speed. In many cases in this country, garbage wagons are built with removable steel bodies, which can be lifted from the truck by a crane and placed on freight cars or scows for removal to the disposal works. Sometimes they are lifted directly

into the disposal plant, and, after dumping, are returned to the wagon frame. This method, depending on the necessary travel for the crane, requires considerable time.

In Milwaukee, where this method was used at the incinerator, it was possible to unload from 20 to 25 wagons per hour per crane. With two cranes working, the capacity of the plant for unloading wagons is about 40 wagons per hour. This is just sufficient to keep ahead of the wagons as they come in. Where many wagons come to one point of disposal, the method of unloading must be carefully considered in order not to keep the drivers waiting.

Fig. 7. Minneapolis Wagon With Canvas Cover.

(7) Wagons are drawn by one, two, or three horses, or are propelled by a motor. Where it is possible to have large wagons, two horses are generally satisfactory. In Paris some of the large wagons are drawn by three horses and the new wagons recently installed in New York are drawn by three horses. The use of one-horse carts does not seem advisable except in special districts.

Recently there has been a great advance in the construction of motor-driven vehicles. Manufacturers are urging their use for refuse collection. In several cities they have been given trials. An electric truck is used in Hamburg, Germany, which has a

capacity of about 5 cu. yds. and cost $4,000. The cost of operation was given as follows:

Tires	4.2 cents per mile.
Power	3.5 cents per mile.
Misc.	1.0 cents per mile.
Total	8.7 cents per mile.

The wagons weigh about 11,000 lb. They are fitted with two electric motors of 4.5 h.p. capacity. They make four trips each night, covering about 35 miles in eight hours. Then the batteries are replaced with others already charged at the city incinerator.

Motor driven wagons have been used in Paris, and in Seattle in this country, for hauling rubbish. The necessarily large number of starts and stops required for this service puts a handicap on most motor-driven vehicles. On the other hand, the fact that larger loads can be handled is a favorable factor. Frequently, where roads to the point of disposal are poor, the weight and unwieldiness of the motor precludes its use. At the present time, its chief usefulness would seem to be for taking the load from a transfer station near the area of collection to an isolated point of disposal.

The Superintendent in Hamburg stated that these wagons were cheaper than two-horse wagons of similar size only when operated two shifts of ten hours per day. In this way the fixed charge was distributed over a larger tonnage of refuse per wagon. It would seem advisable for long hauls to give the motor truck a more extended trial. The saving for short hauls is questionable.

Where horses are used, it is obviously better that they should be capable of hauling a maximum load. It is the general experience that better kept horses, capable of carrying heavier loads, are found in cities that have their own stables. Horses rented by the day, generally from individuals of small means, are apt to be worked on the least feed possible. Two horses weighing 1,500 to 1,600 lb. can work in refuse collection service with a load of about 9,000 lb. net.

OPERATING THE WAGONS.

Different methods of operating the wagons are found in different cities. The so-called "Roller-System" is used in this country in Buffalo, N. Y., and Springfield, Mass. Workmen go down each side of the street about an hour ahead of the wagons. They roll the cans out to the curb. In some districts these men have small trucks with which they roll the cans from the back yard to the curb. The driver empties the cans into the wagon and disinfects them. The workmen then take the empty cans from the curb to the back yard. This method makes the most use of the more ex-

pensive part of the equipment, the horse and wagon costing more than the laborer. Therefore, the system is good where the house can is inaccessibly placed.

The common system abroad is for the householder to place the can on the curb for the collector. In this case, one or two workmen accompany each wagon, one of them acting as driver, while the other empties the can, which is generally small, from the curb into the wagon. This is a very effective method, and, to the writer's knowledge, the most economical in use. Recently bids were asked in Plainfield, N. J., under two schedules: "A", that the householder should set the can out on the curb, and "B" that the collector should carry the can out from the basement. The low bid varied from $12.00 per house per year under schedule "B" to $4.62 per house per year under schedule "A", showing that the contractor estimated the additional cost of having the collector go into the cellar at $7.38 per house per year. For a city of 100,000 people, having say 20,000 houses, this would amount to $147,600 per year.

The common method of operating the wagons in this country is to have the driver make the collection from the back yard. This is uneconomical from many points of view. The horse and wagon must stand idle while the can is being emptied and returned, and the whole collection work is retarded accordingly.

In Milwaukee, as in many other cities, the collection of garbage is planned by districts. The city is divided into small districts, so arranged that each district, when visited at intervals of from six to eight days, yields one load of garbage. Each collector is assigned two districts, so that each has either a long and a short haul, or two medium length hauls; the object being to equalize the work.

It was found in Milwaukee, covering about 25 square miles, with a population of 385,000, that 95 collectors with 1.5 cu. yd. wagons operating in about 200 districts, were necessary. This system has the advantage of familiarizing the collector with certain districts in the city, and complaints can be located and traced directly to the collector at fault. One Superintendent with an office at the city incinerator, has charge of the collection work, the weighmaster serving as his assistant. If it had been possible to secure workmen of sufficient intelligence to co-operate with the householders in their districts, this system would have been satisfactory. As it was, however, the wagons required by the city only carried 1.5 yd. of garbage, and were drawn by one horse. This enabled workmen of small means and often of small intelligence, to own a horse and wagon and to secure the city work. The whole city was too large a unit for one Superintendent to handle, and the collectors, as a general rule, were not able to give to the service anything more than the mechanical operation of their equipment. The result on the whole was unsatis-

factory. The complaints averaged from five to fifty a day, being more in summer than in winter. The city administration recognized that this collection system was not entirely satisfactory. Its plans for improvement were along two lines.

(1) New wagons with a capacity of 4 yd. were purchased and installed for a part of the city. This was expected to reduce the number of wagons required and to secure more intelligence on the part of the collectors.

(2) The Superintendent was to have two assistants, who should devote their time to securing co-operaton between the collectors and the householders.

Before leaving the Milwaukee description, mention should be made of Bulletin No. 12, of the Milwaukee Bureau of Economy and Efficiency, on "Garbage Collection" by Robert E. Goodell. This bulletin gives some very satisfactory data resulting from a field investigation of the collector's work. It was found that the rate of driving was between 3.04 and 4.48 miles per hour. Table IV above shows results of the observations on the time spent in collecting from individual places.

In Minneapolis, is found a system of garbage collection which, in many ways, is similar to that which would have resulted in Milwaukee had the suggested improvements been carried out. The wagons used in Minneapolis have a capacity of 100 cu. ft. This has resulted in securing for the work a higher grade of collectors. The city ordinance requires that all garbage shall be drained of water and wrapped in paper before it is placed in the can. This has been very successfully enforced, so that about 90% or more of the population obey the ordinance. This would not have been possible if the collectors had not secured the co-operation of the householders in their districts. The districting of the city is very much the same as it is in Milwaukee. There is, however, one notable exception. In Milwaukee, ashes and rubbish are collected in the different wards under the ward superintendent. In Minneapolis, ashes and rubbish are collected by districts co-extensive with the garbage collection districts. It is evident that it is better to separate political districts from collection districts, and the results in Minneapolis bear out this statement. It is rarely the case that political districts are divided to meet the requirements of collection districts.

It is interesting to note that, in Buffalo, the garbage collections are made on a schedule so that the collector arrives at each house within a few minutes of a fixed time on a stated day. This makes it possible for the housekeeper to know when the collections are going to be made, and to arrange accordingly. It also enables the Superintendent to follow more carefully from house to house, the work of the collector. In Bremen, Germany, the collector gives notice of his approach to the house by ringing a bell. The

housekeeper is then supposed to set the can out in front for the collector. Where no can is set out the collector assumes that no collection is wanted. This has a tendency to automatically regulate the required frequency of collection. Such a system would not be possible in a crowded, busy district.

The city of Seattle, Washington, has a very carefully worked-out system for collecting mixed refuse. Five refuse incinerators, of which two are in operation, and one under construction, are located in various districts of the city to facilitate the collection service. Wagons having an average capacity of 1.6 tons, or about 3.0 cu. yds., are used, the number required in each district being shown in Table V.

TABLE V.

Collection Data, Seattle, Wash.

District	Tons per day	Wagons	Men for collection	Men at barns
1	107	24	40	4
2	35	11	20	2
3	33	10	17	2
4	93	22	36	3
5	29	7	12	1
Totals,	296	74	125	12

Wagons per 100,000 population—31.

The average cost of collection per ton is estimated to be $2.40. The teams are stated to travel at a rate of 2.75 miles per hour.

The city of Columbus, Ohio, also has a very carefully planned system of collecting garbage, ashes, rubbish, and manure. The city owns its own stable and equipment. The average number of teams employed in garbage collection from January to July, is 17; from July to October, 22, and from October to January, 17. The city is laid out into 31 garbage districts. These are divided among the collectors on the "long and short haul" method, so that no team travels more than sixteen miles per day. Each team collects two loads daily except that those collecting from hotels make three. The loads average 1.5 tons. The cost of operation for the garbage collection service was $1.88 per ton for the year 1911.

For the collection of rubbish, the city is divided into eight districts, each being in charge of a foreman, who has under him about four teams, four drivers, and one helper. Thirty-two teams are employed.

It is worthy of special comment that the city collects the manure. Any person desiring this city service must take out a permit which costs $3.00 per year for one horse, $5.00 for two horses, and $1.00 per horse for all over two. No one is required to take out a permit but everyone is required to remove the manure once in every ten days. If they fail, the city removes it at a cost of $2.00 per load to the stable owner. Six wagons are employed hauling manure.

The cost of collecting rubbish in 1911 was 68c per cu. yd., and of collecting manure, after deducting receipts from permits and the sale of manure, was 32c per yard. The manure is sold for 50c per ton f.o.b. city tracks.

The Ohio State Board of Health has made a very careful investigation of refuse collection and disposal in that state. The following is taken from their report:

OHIO CITIES.

EQUIPMENT AND METHODS OF COLLECTING CITY REFUSE.

(Garbage)

"For the collection of garbage, particularly in the large cities of Ohio, special equipment suitable for the purpose is provided. Two general types of wagons are used. In Cleveland, Columbus, Cincinnati, Dayton, Steubenville, and Zanesville, covered steel tank wagon bodies are employed, and in the other cities studied, the wagons are built with two platforms upon which the cans from the householders are placed directly. The Cleveland and Columbus wagons are of the same type, and are designed for dumping their contents without removal of the wagon bodies. At Cincinnati and Dayton, the wagon bodies are removed from the running gear and subsequently dumped after transportation to the point of disposal. The platform wagons used in connection with the so-called can system, are somewhat less economical than the tank wagons, but are entirely suited for small cities where the quantities of garbage are not great.

"In the smaller cities of the state, the material is transported directly in the collection wagons to the disposal plants, but in the larger cities, where the question of length of haul becomes of great importance, there have been established loading stations, where the garbage may be dumped into specially constructed cars, or left in the wagon bodies which are placed on flat cars and thus transported to the point of final disposal. This method is practiced in each of the large cities in Ohio.

(Rubbish-Ashes)

"Although separate collection of rubbish and ashes is practised in certain localities, it was found that in each of the Ohio cities, in which this work is carried on, these wastes are collected and disposed of together. In only three of the cities of the state are there organized collection systems for this class of material, and in each of the others, private scavengers are depended on. Special types of wagons are used at Cincinnati and at Cleveland, while at Dayton, a modification of the slat-board type of wagon is employed. Local conditions are met at Cincinnati by the use of a back dump wagon manufactured by the city street cleaning department,

and at Cleveland by the use of a bottom dump wagon, of standard make. The type of wagon is not of vast importance, but it seems to be the consensus of opinion that for best economic results, the wagon should have a capacity of from three to four cubic yards, where combined collection of ashes and rubbish is made."

TIME OF COLLECTION.

The question of night as against day collection is a difficult one to decide. The most general practice in German cities is to make collection at night. There is, however, a sentiment against this practice on account of the noise of collection and the danger of having the can stolen where it is set out at night for the collector. In Milwaukee, during the summer of 1910, there was such an outcry against having the collection wagons on the streets during the daytime, that it was necessary to make the collections in the very early morning, from 2:00 a. m. to 8:00 a. m. This worked well during the summer months, when it became light early. During the fall, it became more and more difficult for the collectors to work rapidly in finding the cans in the back yards. It does not seem advisable in residential districts to make the collection at night. In downtown districts, however, it is found difficult to make collections except at night, because of the crowded condition in the streets. Probably for such districts, early morning hours are most satisfactory. Except with mixed refuse, I do not know of any case where ashes and rubbish are collected at night. The Superintendent of Collection at Essen, Germany, received considerable complaint from the dust due to loading mixed refuse into the wagons during the day and was contemplating either night collection, or a new type of covered wagon on this account. There is undoubtedly dust nuisance from ashes on windy days passing through the streets in uncovered wagons.

SEPARATE OR MIXED COLLECTION.

Another question in refuse collection difficult to answer, is the relative merits of mixed as against separate collections. Referring to the expressions for refuse collection as given above, a computation can be made of the relative cost of separate and mixed collection under similar conditions of service. Assuming four-yard wagons with collections at three-day intervals, the same quantities of refuse, and the average time of collection per house at three minutes, computation based on the equations as given above, shows that for separate collection the total number of wagons required per 100,000 population will be 220; for mixed collections, using the same assumptions and quantities, the number of wagons required is 76. In practice, it is always found that collections at three-day intervals are not necessary for ashes and rubbish. On this account, the theoretical difference between

separate and mixed collection as shown above is not evident in practice.

The following table shows the number of wagons and the capacity of the wagons per 100,000 population for mixed refuse collection at Seattle, Wash., and for separate collection at Columbus, Ohio:

Columbus, Ohio.

Population (1910) 181,511.

For ash collection }	22	wagons of 3.0 cu. yd. capacity.
For rubbish collection }		wagons of 4.0 cu. yd. capacity.
For garbage collection	11	wagons of 2.5 cu. yd. capacity.
Total	33	Average 3.2 cu. yd.

Seattle, Washington.

Population (1910) 237,194.

Total	31	wagons of 3.0 cu. yd. capacity.

Very little actual data relative to the cost of collection under these two systems are available. Aside from the cost feature, it may be said that mixed collection will make it difficult for flies to propagate in the garbage, will tend to lessen the dust nuisance from ashes, and will partly prevent the flying away of loose paper from the rubbish. On the whole, mixed refuse is a cleaner material to handle, and excepting as the separate collection may be cheaper, both as to collection and disposal, the mixed refuse collection is best.

One of the things shown by this discussion is the extreme variation of the cost and methods of refuse collection. There are several causes for this difference. Local conditions, as to length of haul, street grades, and the co-operation of the householders, have an important effect, and also the efficiency of the department handling the work. It is also true that the methods of keeping records and accounts in the department have an important effect.

Where only scattering loads of refuse are weighed, or where the weights are computed from wagon loads, without actual weighing, the tendency is to increase the tonnage and to reduce the unit of cost of collection. There is probably no branch of municipal work in which accurate data are of more value than in refuse collection. It would seem advisable to make up the records accurately, and in some standard form so that they would be of value for comparative purposes. The writer recently presented to the American Public Health Association a suggested standard form of statistics for municipal refuse. The adoption of some such method for keeping records would lead to a more general use throughout the country of those methods of refuse collection which experience has shown capable of producing the best results.

Discussion.

J. L. Jacobs, (Efficiency Engineer, City of Chicago): The Society is to be congratulated in having Mr. Greeley present a paper on this broad and important subject. Experiences in this work will indeed be of use and help for an effective solution of this great municipal problem. The subject, to my knowledge, has never been taken up in as excellent a manner as treated this evening. It is particularly unfortunate that more engineers and citizens, all of whom are directly or indirectly affected, are not here tonight. The discussion of this subject in the city of Chicago, where an amount aggregating $1,200,000 annually is expended for the collection, hauling, and disposal of municipal waste, attracts only thirty people. How can one expect to have better service and effectively and economically administered, when the public itself is not sufficiently interested?

It has been my experience that good, effective service in municipal government can be obtained only by spiritful interest of all citizens. This may be obtained by constant publicity campaigns. The Western Society of Engineers, in inaugurating such campaigns of publicity amongst all citizens, should accomplish more good than it can in any other way.

The problem of garbage and refuse collection and disposal has been given as little concerted study in this city as in any other place. No scientific inquiry of this great question has heretofore been made here, and until very recently no one seemed to think that the problem was one that required any scientific study or solution. Under these conditions, one could hardly expect most effective methods and sanitary conditions, and economical administration of this complex municipal function. I do not want to be understood as intimating that the conditions existing here are worse than those in any other city. It is purely a result of abnormal growth of an activity in an expanding municipality, and no one has been given sufficient time to solve it. With the growth of cities and the increasing stringent requirements for sanitary conditions, demand has been made for better methods and systems. The subject is now being taken up more thoroughly and scientifically than ever before, and in many of the European cities much has already been accomplished as a result of such study.

During the sittings of the Committee on Finance of the City Council last year, while preparing the 1912 appropriation bill, the question as to what were equitable appropriations for the different sections of the city for the collection and disposal of municipal refuse and garbage, and cleaning and repair of streets and alleys, was taken up, but left unsolved, because of insufficient data at hand. It was then decided that in order that the appropriations for these activities be provided where most needed, and where the greatest good could be obtained, scientific study should be

given to the entire question. The discussion during the past few months in regard to the economy and advisability of again contracting for the reduction of garbage, further emphasized the need of a thorough, scientific study.

Accordingly, the Committee on Finance of the City Council requested that the Efficiency Division of our Commission immediately take up the entire question, report and formulate plans whereby the appropriations and expenditures, aggregating annually approximately $2,500,000, will be more equitably and effectively distributed. This investigation was begun the latter part of July of this year, and the regular staff of the Efficiency Division, with a temporary force of engineers, is now engaged day and night in the great task. We plan to have a preliminary report covering the most important matters ready for use in preparing the 1913 appropriations for these activities.

In order that this huge problem may be solved in its entirety, the study should be continued after the preliminary report is issued. Definite standards, schedules, and units should be established for use of the department in all future work. With the establishment of schedules based upon the actual needs and requirements of each district, and units based on actual work, we will be in a position to insure more effective service and greater economy.

A very important matter excellently treated by Mr. Greeley in the latter part of his paper, namely, the need of units and cost records, should be especially mentioned in this connection. We have not been able to find any uniform records of the above activities in this city. Such records as are available are not in such shape that they are comparable or subject to analysis. The only way one may know how effectively and economically work is performed, where leakages exist or occur, and where good or bad conditions obtain, is by maintaining permanent records of each division or unit of work. Any standards adopted should be of such a character that they would be applicable to any district in a city or to any municipality. Each unit should be distinct and definite, so that when analyses of records of other offices are made, it would simply be a matter of substituting the definite unit in each particular case, and results will then be comparable.

The figures given by Mr. Greeley of the time spent in the collection and hauling of garbage are interesting. It is clearly indicated that each may be treated separately. Units so established will make it possible to ascertain where it is profitable to collect refuse and garbage together or separately, and where the cost of haul has reached a maximum requiring additional loading platforms or stations, or requiring new methods of hauling.

There is one matter dwelt upon by Mr. Greeley in which I am particularly interested and which we have under consideration in our investigation at this time, namely, the division of productive

and non-productive work in the collection of refuse or garbage. He states in his paper that the productive work stops at the time when the man has filled his wagon. The period taken in hauling the refuse from the platform or disposal station is listed by him as non-productive. That, to a certain extent, would be truer in a small city where the haul is not appreciable, or where it is possible to unload immediately after the wagon has been filled. In a city the size of Chicago, or any city spread over a great area, this is not the case. In this city the hauling of refuse or garbage is as great a division of necessary work as the collection proper. In this city between one-third and two-fifths of the total amount of money spent on general collection (as treated by Mr. Greeley) is spent for hauling, i. e., about $400,000 is spent annually for hauling garbage and refuse to the dumps, platforms or plant, and about $300,000 is spent for collection proper. The hauling, therefore, is of sufficient importance in the larger cities to be treated separately from the collection proper, and I would say that instead of dividing the entire problem of refuse disposal into three divisions of house treatment, collection, and disposal, it should be divided into four divisions—house treatment, actual collection, hauling, and final disposition. By this division it would be possible to obtain actual units of cost of collection per ton, hauling per ton mile, and the disposal per ton, each being considered separately and distinctly, and schedules and plans arranged for each, according to conditions existing in any district.

As stated before, we are spending about $400,000 a year in hauling refuse and garbage to dumps, to platforms, and to the reduction plant. Herein lie possibilities of great savings. We are now making a study relative to the location of additional loading stations, the use of electric and steam railways for transportation, as well as the hauling of the refuse and garbage by motor trucks. I understand there are gentlemen here this evening who have given considerable time and study to the cost and effectiveness of motor trucks for these purposes, and some figures in that connection would be very interesting.

F. H. Cenfield, ASSOC. W. S. E.: The collection and disposal of municipal waste is one of the most serious problems that confronts every large municipality. A great many articles have been published by engineering and municipal papers, giving results obtained in different cities and also detailed descriptions of plants in use. However, very little information is available regarding the method and cost of collection and the cost of disposal, on account of the lack of uniformity in the method of keeping records, and also the fact that a large proportion of this work is done by contract and, therefore, cost amounts are carefully kept from the public and from competitors. Whenever a standard form of accounting for this

branch of the municipal service can be adopted by all large cities, a great step will be made towards the proper solution.

The collection and disposal of municipal refuse has in most cases been treated as a condition to be overcome in the easiest manner possible rather than as a problem to be solved. This municipal activity is an engineering proposition, involving problems of both a civil and mechanical engineering nature, and not until cities approach the problem in this manner will a proper solution be reached.

All public collection of municipal waste in Chicago is done under the direction of the Department of Public Works, Bureau of Streets. All private collection and disposal of refuse is done under the general inspection and supervision of the Department of Health. The collection, as well as the haul to the point of disposal or to loading-stations, is done by teams and wagons. Garbage is separated from ashes and rubbish by the householder and kept in separate receptacles. It is collected by wagons equipped with steel boxes and is hauled to the disposal-plant by these wagons or to loading-stations where the boxes are loaded onto barges and are transported by water to the disposal-station.

Ashes and rubbish are collected in 5-yd. wooden boxes and hauled to either clay hole or marsh land dumps direct, or taken to loading-stations and transported either by train or trolley to other clay hole or to marsh land dumps.

The operation of the two garbage loading-stations on the north branch of the Chicago River, as well as the operation of the two loading-stations for ashes and rubbish, has been a large step in the direction of reducing the time and cost of haul, and hence the unproductive work to which Mr. Greeley alluded.

Colonel Zinn, in a paper delivered before this Society on February 5, 1912,* gave some figures regarding the cost of various methods of transportation. It was stated that the cost of transporation by wagon was 50 cents per ton mile. Wherever possible, water transportation should be used, as it furnishes the cheapest method. The use of power tractors also seems entirely practicable. This phase of the problem is intensely interesting from an engineering standpoint.

The various classes of municipal waste output have wide seasonal variation. As a general rule the production of garbage is a minimum during January, February, and March, increasing from the latter month gradually until June. Through July, August, and September the output is very high, reaching the highest point in September. The maximum production of ashes and rubbish occurs during the winter months and the low point occurs during the summer months. Efficient handling of these products necessitates that those in charge must be alert to these changing conditions, and

*Journal, Vol. XVII, No. 4, April, 1912.

must maintain an organization and an equipment which is flexible enough to be adapted to the problem at hand.

The collection and disposal of the refuse of a large municipality is a proposition which affects every citizen, the amount of money necessary to properly perform this function is very large, and the sanitary condition of a community largely depends upon the service given, yet few realize the importance of the problem. The problem is not a theoretical, but a practical one. All conditions affecting it must be thoroughly investigated with all information attainable on the subject. The plan finally adopted must be the one which will meet the needs of the municipality in the most efficient and sanitary way possible for the conditions existing.

W. E. Symons, M. W. S. E.: Mr. Greeley's very interesting paper has furnished much food for thought, not only for those who are familiar with the details of garbage and rubbish collection and disposition, but for others whose experience has been in other lines of activity.

I recall the presentation before this Society, something like one year ago, of a paper on a subject which involved many complex scientific and engineering problems. After some delay, it was suggested, in a somewhat humorous vein, that no knowledge of the subject was necessary in order to discuss it, after which the discussions were quite general and spirited. If this qualification applies tonight, then I shall not feel it incumbent upon me to offer any apology for speaking on a subject with which I have had no experience.

The question of collection and disposal of garbage, refuse, ashes, etc., is not wholly one of handling cans, boxes, shovels, etc., but in the last analysis it is principally one of transportation, and viewing it from the transportation standpoint, I find myself quite familiar with most of its important factors.

The question of efficiency, or cost, is of course the principal one, and by reference to Table I the following costs may be observed:

	Cost per Ton
Chicago.	
For Collection	$3.42
For Disposal	.38
Total	$3.80
Columbus, Ohio.	
For Collection	$1.88
For Disposal	.77 profit
Net cost per ton	$1.11
Difference in favor of Columbus, Ohio	per ton, $2.69

Doubtless local conditions have much to do with this wide range of difference in price. As the figures for Chicago are the highest of all other cities, however, there seems to be an inviting field for the student of economic transportation.

The question of economy, or efficiency, in this and similar matters, is really a question of the relative efficiency of horses vs. motor trucks, and this in turn involves questions of political economy and the cost of living.

In treating the subject from this point of view, I feel that I am not digressing from the underlying spirit of the text of the author's paper, but rather amplifying a phase of the problem that is scarcely touched upon, but which, in my opinion, should receive the attention of all those interested in matters of this character.

HORSES VS. MOTOR TRUCKS.

Through the kindness of Mr. Akers, of the City Club of Chicago, I have secured some extracts from statistical data prepared by Mr. Rex, Assistant City Statistician, from which I quote the following:

Number horses in Chicago, 1908	83,333
Number horses in Chicago, 1912	72,670
Decrease in 4 years	12.78%
Number commercial motor vehicles, 1908	68
Number commercial motor vehicles, 1912	1,400
Increase in 4 years	1,958%
Total all kinds vehicles, 1908	65,125
Total all kinds vehicles, 1912	71,143
Increase in 4 years	9.24%

From the foregoing figures various calculations may be made and certain conclusions drawn.

If these 72,670 horses were all used in two-horse teams with an estimated length of 30 ft., their total length would be 1,090,050 ft., or 206.44 miles. By substituting motor trucks for these teams with a length of 20 ft. each, their total length would be 726,700 ft., or 137.63 miles, or a return to the city of 68.81 miles of street space in its most congested districts.

Assuming that the street length thus restored averages 8 ft. in width, and is valued at $40,000 per acre, then its value would be approximately (for 48.4 acres) $1,936,000.

Motor trucks accomplish more at a much faster rate of speed than horse vehicles. If motor trucks were substituted for horse vehicles, on a basis of the present street area occupied by the latter, then the increased tonnage facilities (based on an average load of 3 tons to each unit) would be approximately 39,726 tons.

In comparing the relative efficiency of motor trucks to horse vehicles, however, the item of reduced space occupied by the former is only one of its many advantages.

The term efficiency, when unqualified in its application to practical transportation problems, is a most variable element, and in many cases has proved very disappointing. To be specific and provide an equable basis of comparison, therefore, the term *sustained efficiency* will be used as the relative measure of worth,

value, or service, and by this standard we have so far progressed beyond the period of horse efficiency, from a standpoint of *tonnage, speed* or *endurance,* that it seems like a pronounced step backward to even make the comparison. I shall therefore pass the details of this feature to take up another of much importance to all students of political economy, for the cost of living is of national importance.

There are in the United States and Canada 27,300,000 horses. On a basis of 3 acres of land to each horse, it requires, for their food alone, 81,900,000 acres of our most fertile cultivated land. By the same authorities it is estimated that ten persons can live from the same area required to sustain one horse, and on this basis the soil area now required to provide food for our horses would provide food for 273,000,000 people, while motor trucks that are more efficient and economical for most of the work, exact no toll from the surface of the soil whatever, as they are *fed* from the product of crude oil drawn as needed from nature's storehouse in the "bowels of the earth."

In this city there are, as previously noted, 72,670 horses, of which number it may be assumed that 90% should be displaced by motor trucks, leaving 7,267 horses in the city in place of 72,670. This would not only aid greatly the sanitary conditions in the city, but would transfer the products of about 186,509 acres of tillable soil to the uses of man, and thereby provide food for approximately 655,030 people.

From the *Commercial Vehicle* I quote the following statistics:

Chicago burns 14,000,000 tons of coal every year.

Chicago burns about 42,169 tons of coal every day.

It costs 30 to 50c per ton, or say, an average of 40c per ton, to deliver coal, or about $5,600,000.

If conditions were favorable to the use of motor trucks this coal should be delivered at about 15c per ton or, say, $2,100,000, a saving of $3,500,000.

From the foregoing some interesting calculations may be made.

Assuming the average load to be 4 tons to each horse vehicle, with two trips per day, it would require 5,271 teams. while if 6-ton motor trucks were used, making three trips per day, only 2,342 units would be required, or a saving of 2,927 units, while the street space thus saved in a congested traffic district is of much value to teaming, street cars, pleasure cars, and pedestrians.

In applying the foregoing to the garbage department, we find an inviting field for its economic operation.

From figures kindly furnished me by Mr. Jacobs, Efficiency Engineer of the Civil Service Commission, the operation and expense to the city of collecting ashes and rubbish, and collecting and disposing of garbage in 1911, was about as follows:

ASHES AND RUBBISH, 1911.

Number teams employed (estimated)	420
Number loads per day	863
Cubic yards per day	4,317

Cost of collection, per year	$ 826,437.67
Cost of collection, per day	2,665.92

GARBAGE, 1911.

Number teams employed (estimated)	200
Number tons handled by teams	63,969.75
Number tons handled per day	206.35
Number tons handled per team per day	1.03
Total teams in both services	620
Total expense, both services, per year	$1,273,178.14
Total expense, both services, per day	4,107.02

To one not familiar with the details of operating this department it would appear that the use of motor trucks could be at least partially installed in place of horses, and thereby reduce the cost per ton and the net expense per year. Doubtless Mr. Jacobs has already given this matter sufficient study to be able to throw some light on the subject.

In addition to the item of tonnage and space already referred to, the question of the speed of street traffic, *in procession,* is an important one.

The speed of street traffic is governed by the speed of the slowest team or unit. Sometimes a long line of valuable teams, pleasure cars, and commercial vehicles is held to a snail's pace by half-starved blind horses enduring the torture of a cruel driver while attempting to haul a double load on a ramshackle wagon. As an evidence of the effect of these antiquated conditions of street traffic, the following approximate speeds at certain important points are taken from the figures prepared by a gentleman who has given this matter considerable attention:

Street	*Time*	*Approximate Speed in Miles per Hour*
Rush	9 A. M.	5.11 miles
State	10 A. M.	2.86 miles
Clark and Wells	10 A. M.	2.55 miles
Dearborn	11 A. M.	2.58 miles
Dearborn	9 A. M.	2.04 miles

Even if it were possible to eliminate the decrepit horses from the streets, the *best* horses are frequently overloaded, and again, weather conditions frequently render it impossible for them to move an average loading without slipping and falling, which causes much delay. These objections, together with the much greater length of horse vehicles as compared to motor trucks, also the insanitary features of the horse, afford ample grounds for their elimination *by law* from certain congested districts of cities, particularly in the city of Chicago.

It is probable that there are several gentlemen here this evening representing some of the leading manufacturers of motor trucks, who have analyzed these comparative cost problems and are prepared to give the costs per day, per ton mile, and from various other

angles of comparison. I will leave those details to the gentlemen who are better able to speak on them.

C. C. Saner, ASSOC. W. S. E.: The following is the cost of collection and disposal of rubbish, ashes, and garbage for the last ten years in Evanston:

	Ashes		Rubbish		Average Cost
Year	Cubic Yards	Cost	Cubic Yards	Cost	Per Cubic Yard
1901	7,871	$1,566.35	14,653	$2,122.05	$0.1637
1902	8,108	1,268.24	15,786	2,532.13	0.1590
1903	8,733	1,567.38	15,808	2,672.82	0.1728
1904	12,993	1,874.81	17,755	3,157.16	0.1636
1905	12,191	1,635.39	22,465	3,441,42	0.1465
1906	11,826	1,708.55	24,291	3,918.09	0.1558
1907	12,923	2,409.00	24,864	4,283.50	0.1768
1908	14,433	2,713.00	26,096	4,967.00	0.1894
1909	13,272	2,471.75	27,156	4,863.15	0.1817
1910	13,461	2,174.00	29,479	5,108.00	0.1696

GARBAGE.

	Tons Removed	Cost	Cost Per Ton
1901	2,709	$2,220.50	$0.8197
1902	2,523	1,995.92	0.7911
1903	2,628	2,109.31	0.8026
1904	2,650	2,290.87	0.8645
1905	2,818	2,661.60	0.9445
1906	2,860	2,743.72	0.9593
1907	2,929	3,005.00	1.0259
1908	2,627	2,980.00	1.1343
1909	2,716	2,970.00	1.0935
1910	2,800	3,186.00	1.1379

In 1906, 2,860 tons of garbage were delivered to the city yards by city wagons, to contractors who hauled it from the city. The cost was $100 per month, or 42c per ton.

1907—

During the months of January to May inclusive the city disposed of its garbage by contract at $100.00 per month. The city collected the garbage and delivered it to contractor's wagons at city yards. During the months of June to October, inclusive, the city operated its crematory. During the months of November and December farmers took the garbage from the city yards.

The cost of disposing of the 2,929 tons of garbage collected by the city was as follows:

1,158 tons removed by contract	$ 500.00
1,308 tons cremated	753.63
463 tons removed by farmers	
2,929 tons disposed of	$1,253.63
Add cost of collection	3,005.00
Total cost of collection and disposal	$4,258.63
Average cost per ton, $1.454.	

Farmers collect considerable garbage in advance of city teams. Many

residents dispose of their garbage. Hence the amount of garbage produced is much greater than amount collected by city.

1908—

Removed by contract	20 tons
Removed by farmers	2,325 tons
Cremated	282 tons
Total	2,627 tons

COST OF COLLECTION AND DISPOSAL OF GARBAGE.

Collection of garbage	$2,980.00
Removal of garbage by contract	20.00
Operating crematory	543.00
Total	$3.543.00

Average cost per ton, $1.3487.

1909—

Removed by farmers	2,047 tons
Cremated	669 tons
Total	2,716 tons

COST OF COLLECTION AND DISPOSAL OF GARBAGE.

Collection of garbage	$2,970.00
Operating crematory	783.24
Total	$3,753.24

Average cost per ton, $1.3819.

1910— DISPOSAL OF GARBAGE.

Removed by farmers	2,317 tons
Cremated	483 tons
Total	2,800 tons

COST OF COLLECTION AND DISPOSAL OF GARBAGE.

New steel smokestack was erected at garbage crematory, costing...		$265.00
Repairs made to furnace cost		109.86
Total cost of all repairs to crematory		$374.86
Paid for fireman	$240.00	
Paid for fuel	333.34	573.34
Total cost of operation and repairs for crematory		$948.20

Garbage collected and disposed of, 2,800 tons.

Cost of collection of garbage, $3,186.00.

Cost per ton for collecting garbage = $3,186.00 ÷ 2,800 = $1.1379.

Cost per ton for collecting garbage and operating crematory = ($3,186.00 + $573.34) ÷ 2,800 = $1.3425.

Cost per ton, based on collection of garbage, repairs to and operation of the crematory = ($3,186.00 + $948.20) ÷ 2,800 = $1.4757.

SUMMARY.

Year	Tons	Cost Collection	Cost Per Ton	Cost of Disposal	Cost Per Ton	Total Per Ton
1907	2,929	$3,005.00	$1.026	$1,253.63	$ .427	$1.454
1908	2,627	2,980.00	1.1343	543.00	.206	1.3487

1909	2,716	2,970.00	1.0935	783.24	.288	1.3819
1910	2,800	3,186.00	1.1379	948.20	.338	1.475

From the Summary it will be seen that the cost of collection of garbage is much lower, and the cost of disposal a little higher, than the average of the cities given in Table 1.

The method of collection and disposal is as follows: The city is divided into eight territories. These territories are made up according to the number of pick-ups and the distance of the routes from the yard. Collectors have single-horse wagons and collect two loads a day. These wagons are ordinary wooden boxes, an oil tarpaulin being used for a cover when the wagon is loaded. The collector brings these loads to the city yards, which are centrally located, and delivers them to the farmers or the crematory. From October to May the farmers take all that is collected. During the remainder of the year part of it has to be burned, as farmers cannot leave their harvest. A concrete roadway has been constructed, on which garbage is transferred from the city to the farmers' wagons. The collector's wagons are cleaned out with water every evening. The concrete roadway is cleaned twice a day.

Taking the population of Evanston at 25,000, the per capita production of garbage was 224 lb. for 1910, or 0.187 cu. yd.; rubbish, 1.179; ashes, 0.538; total, 2.904 cu. yd., or 0.212 cu. ft. per capita per day, an amount about twice as much as that quoted in the paper of the evening.

This year we purchased a paper-baling machine and placed it on a wagon. The wagon is drawn by one horse and is attended by one man. Seven or eight bales of paper weighing about 85 lb. each are brought in each day. The value of this paper is about $1.50. The rubbish wagons are of the drop-bottom type, of 2 yd. capacity, drawn by two horses and attended by one man. Two yards of loose paper, or one wagon load, can be pressed into one bale. It is easily seen that the value of the paper brought into the yards is a clear gain, and the thought of a good team hauling less than 100 lb. to the dump is rather amusing.

A careful watch must be kept of collectors. Some will leave the yard and start collecting at the point nearest the yard and finish at a point farthest away, making the long haul with their load. There are many other minor points that must be guarded against. Some customers wish service every day and will pay the collector to make such a collection; the other people on the route necessarily suffer. We collect garbage three times a week throughout the year. A good, live inspector working with a good complaint system is very desirable in any small city. We furnish our inspector with a motorcycle and find that his efficiency is raised very materially.

November, 1912

Garbage collection has decided peak loads. The peak load is on at present. Extra wagons must be provided for the peak load. If cities had scales on which all their loads of garbage could be weighed, peak loads and the methods of caring for them could soon be determined.

The rubbish, ashes, and street sweepings of Evanston are disposed of at the Lake Front. The filling is carefully done, the street sweepings being placed on top. About 15 acres of park have been made in this way, one acre being added each year.

A. B. Segur: I would ask Mr. Symons what application he would make of a motor truck in the collection of garbage. In the city of Chicago we find that a garbage wagon, making collections, stops on an average of every 50 ft. The average wage per man in collecting is $15.00 per week, and this man helps to gather the garbage from the houses and to bring the cans to the wagon to load. It would appear to me, although I am not very well versed in the subject of motor trucks, that in the case of a motor truck a man in that service would have to be in some position to start the lever and he would have to keep his engine going at all times. It takes three hours and fifty-five minutes throughout the city to collect one load of garbage. That would mean that during three hours and fifty-five minutes the engine would have to be burning the same amount of gasoline that it would be burning during the heaviest part of the haul, or approximately so.

I would also like to know what is the size of the Milwaukee wagons spoken of in the paper.

In Mr. Saner's figures, it seemed to me, if I understood him correctly, that he included in the disposal, the cost of carrying the material from the central disposal plant to the incinerating station. I do not know whether that is true or not.

I would like to know what time it takes for the collection of a load of refuse or garbage in Evanston, and also what the cost of teams and men is per day. I ask simply as a matter of information and not as a matter of criticism.

Mr. Saner: One horse hauls about 1.5 yd. The men are paid $2.40 per day. We own our horses and keep them at the yards, the cost for keeping a horse being about $20.00 per month at present. The cost varies a little during the year, hay costing about $23.00 per ton in the spring and about $14.00 now. The cost of oats varies in like proportion.

The crematory is located at the yards, so that the costs I gave were for contractors hauling to the country.

The table, Fig. 8, shows the time to collect garbage, but does not include unloading at the yards.

CITY OF EVANSTON.

DATA REGARDING GARBAGE COLLECTION

OCTOBER 1912

No	Name	Stops	P Time	U Time	T Time	P Miles	U Miles	T Miles	P.T. / Stops	U.T. / Stops	T.T. / Stops	P.M. / Stops	U.M. / Stops	T.M. / Stops	P.T. / P.M.	U.T. / U.M.
1.	Gatz	389	7h-05m	h 25m	7h-30m	15.5	1.0	16.5	1.10m	06m	1 16m	.0399	00258	.04248	27.4	25.0
2	Perry	153	3-20	20	3-40	7.7	0.7	8.4	1 31	13	1 44	.0504	00457	.05497	26.0	28.6
3	Marion	335	6-20	1-20	7-40	6.0	3.6	9.6	1.17	20	1 57	.0179	.0108	.0287	63.5	22.2
4.	Detloff	400	7-53	47	8-40	7.4	1.7	9.1	1.18	.12	1 30	.0185	.00425	.02275	65.5	27.6
5.	Schroeder	464	9-25	1-15	10-40	10.2	3.8	14.0	1.22	16	1.38	.0220	.0082	.0302	55.3	19.7
6.	Leavell	476	9-15	1-35	10-50	15.4	2.7	18.1.	1.17	.19	1.36	.0324	.00567	.03807	36.0	35.2
7.	Timay	480	10-53	2-47	13-40	11.9	11.2	23.1	1.36	.35	1.71	0248	.0233	.0481	54.9	14.9
8.	Hirsack	540	7-39	54	8-33	8.4	2.7	11.1	1.03	.08	.95	0155	.005	.0160	54.9	20.0
9.	Bowers	555	12-27	2-58	15-25	14.2	9.2	23.4	1.35	.32	1.67	.0256	.0166	.0422	52.6	19.4
	Total	3792	74-17	12-21	86-38	96.7	36.6	133.3	10.89	1.61	12 34	.2470	.08097	.32347	436.1	212.6
	Average	421.3	8-15	1-22	9-38	10.7	47	15.4	1 21	13	1 37	.0274	.009	.03593	38.5	23.6

NOTE P = Productive
U = Unproductive
T = Total

J. H. Moore Commissioner of Public Works
C. C. Saner Deputy Commissioner of Public Works
H. H. Sherer Supt of Streets.

Data collected under supervision of Mr H H. Sherer by
Mr R. Lindsay, Alley Inspector.
Distances measured by cyclometer on bicycle

Fig. 8.

Mr. Symons: Referring to Mr. Segur's questions, as previously stated, I have had no personal experience in the handling of garbage, but I have had occasion to investigate the relative merits of motor trucks as compared to the use of horses. Recently I was called upon by certain banking interests to make a thorough investigation and report upon the present state of the art, and the future possibilities of the motor-truck industry. I found that there are in use more than 859,000 pleasure cars, and about 840 are being built per day. There were, on the first day of March, 1912, 30,000 commercial trucks in service, and about 200 are being built per day. The probabilities are that within the next ten years there will be over 450,000 commercial trucks built and placed in service, aside from those built by people who are manufacturing farm machinery. The relative comparison of horses versus motor trucks varies all the way from 1% up to as high as 50%, 75%, 100%, and sometimes more, in favor of motor trucks.

In the particular case mentioned, I would say offhand, and as a general business proposition, that the superiority of the motor truck over the horse vehicles, where there is a question of either speed, tonnage, or endurance, is so great that the additional help required (if any) to load the truck, without the present delay in which the driver frequently gets down and helps to dump the ashes or garbage, as it may be, would be more than offset. I should think that to the large truck could be assigned one or two more men so that it would not more than momentarily stop while it was being loaded, and that the use of fuel by the engine during this temporary stop would be practically nothing. In fact, when compared to the relative cost of maintenance of the horse truck, the amount of fuel used would not much more than offset the relative cost of food that the horses consume while they are standing still.

In addition to this, one of the most important features is that, under reasonable limitations and conditions, the motor truck never gets tired. Horses do not work an average of four hours per day the world over, or one-sixth of the time, and after they are fed and kept during the long periods of idleness they may suddenly die. Then the entire investment is gone. When a horse is worked to its maximum on any given day, either winter or summer, when night comes it must be fed and allowed to rest, to regain strength for the next day. During Sundays, holidays, or any other period when horses are not earning money, they require just as much food (which is about an average of 50c per day) as when they are working. On the contrary, a motor truck does not require food and rest at night, and, if necessary, another driver can run it all night. The motor truck engine, when shut off, does not require any food, and when it is fed the food is taken from the bowels of the earth rather than from the surface. No toll is exacted from the surface of the land to support motor trucks.

As cities get larger and are more congested we should elim-

inate, within reasonable limits of cost, everything that tends to make them insanitary, and we should not retain a large number of horses in the center of a city if we can provide any other means for handling the garbage and for handling vehicles, because the horse only adds to the amount of garbage and insanitary conditions.

I should say, generally speaking, that the increased efficiency of the motor truck, due to its greater capacity, speed, and endurance would more than offset any additional expense incurred in securing a quicker loading, or due to the motor being operated or allowed to run during these short periods of temporary rest while the garbage is being loaded into the wagon.

Mr. Burdick: I have been inclined to regard anything in the nature of an automobile as a liability, but it begins to look to me now that perhaps I may consider it as an asset.

A. Bement, M. W. S. E.: Referring to Fig. 6, illustrating a wagon containing the packages wrapped in paper, I would ask Mr. Greeley if the scheme has been successful and whether it is popular in Minneapolis. I have heard of this method, and have wondered how the people like it.

We have found, in my home, that it pays to wrap the kitchen refuse, which is the only refuse we have, in paper. It not only pays, but it is more convenient, more comfortable, and for purely selfish reasons—although there are others justifying it—we wrap everything into a nice, clean package, and tie a string around it. I think this scheme of tying the garbage in a package, even if it is put in a can in the alley or at the back fence to be gathered by a wagon, is a very good one.

Referring to disposal rather than to collection of garbage, in recent years there has come into service a device called a garbage burner, used largely in apartment houses. It has a small boiler for heating the water that is used in the house, and it is arranged in such a way that it will burn certain rubbish, such as boxes or wrappings that come from grocery, crockery, and dry goods stores. I do not see why this method could not be used in some of the large residences as well as apartment houses. I live in an apartment house, where there is a garbage burner, and we find that the scheme works very nicely. There is a chute that goes to a can in the basement; we drop the package down into the can and the janitor takes the can to the garbage burner and burns the packages. It is a very nice, clean scheme, and I think it should be encouraged.

Mr. Saner: In regard to wrapping garbage, we have made an investigation, and find it a very good method where incineration is employed for disposal, but this method cannot be used where the garbage is being fed to swine or chickens.

The City Council of Evanston has passed the following order:

1. The property owners in groups of lots not less than 75 to make a deposit of $2.00 per family with the city; said deposit to be paid in advance and to entitle the depositors to the service for a period of four months.

2. The city to furnish metallic receptacles of approximately 1 cu. ft. capacity, and in sufficient number to insure a clean can being left with subscriber at each collection.
3. The city to collect the garbage approximately every other day.
4. The city to have the right to require the subscriber to separate the garbage from glass, crockery, papers, and water, and, if found desirable, to require the garbage to be drained and wrapped in paper, and to enforce such further reasonable regulations as may be found necessary.

I understand that such a service is furnished at Kent, Ohio, and Oakland, California. Enough people have not subscribed as yet in Evanston to give this a trial.

Mr. Bement: I think possibly I have just now gained some information. Recently, at our house, we had pork chops that seemed to me the worst meat I ever tasted; it was both tough and of a bad flavor. I am wondering if that pork came from Evanston. But, joking aside, I have thought many times of the practice of feeding garbage to pigs and have questioned the desirability of that practice for the general good of the community. I have sometimes felt that it should be prohibited, and would like to have some information on that particular point, if any of the gentlemen can furnish it.

Closure.

Mr. Greeley: I think Mr. Jacobs' suggestion of dividing the collector's time into the time spent collecting and the time spent hauling is a very good one. It makes the distinction much clearer.

Someone asked the capacity of the wagons in Milwaukee, on which Table IV, showing data with reference to the collection work, was based. The capacity is 1.5 yd., as mentioned later on in the paper.

I am glad that Mr. Saner presented the data he did, for that is just the kind of information we want to get from cities. It brought to my mind this point: that if a great many cities had that sort of information, followed out on a uniform basis, it would be much more serviceable than if they had it in a variety of different ways, for instance, by the yard, by the ton, and by the load. That is frequently the way we find the data recorded now, sometimes without even giving the contents of the load, and in many instances weights are recorded without a check weighing of the wagon. I know of one city where the recorded quantities in the Commissioner of Public Works' office over a period of several years was something like 25% in excess of the actual weights collected when every load was weighed, the record being based on two or three weighings made each year. I think that some uniform standard method of compiling statistics would be of much value.

With reference to details of motor trucks, a gentleman familiar with that subject once told me that electric trucks could be used for starting-and-stopping service better than trucks using gasoline or oil fuel. That seems reasonable. I do not know just how the relative economy would work out even on that basis. It seems to

me that at the present time the chief use of a motor truck is in the shortening of the wagon haul by taking the refuse from transfer-stations or loading-stations in small districts to a point of disposal, saving the team haul in that way.

I have been told by Dr. Hall, Health Commissioner of Minneapolis, that the wrapping of garbage in that city is very popular; that the people like it and find it, as was said, very much cleaner and neater.

With regard to the garbage burner in private residences, I made an investigation for a company that was building such small garbage burners, and found that the cost to the householder for the operation of one of those burners was considerably more than the cost of disposal through the municipal service. No credit was given, however, for the hot water produced which would have to be furnished by gas or coal. It is quite possible that in flats or apartment houses the cost would be materially reduced; but for individuals I found the cost was greater than the cost of the municipal service.

There is a good deal of difference of opinion with regard to the safety with which garbage can be fed to hogs. Dr. Chapin, Health Commissioner of Providence, Rhode Island, one of the leading health officers of the country, who has written, as you know, probably the greatest book in this country on municipal sanitation and is a very close student of all sanitary problems with relation to public health work, has come out very strongly in favor of the disposal of garbage by feeding it to pigs. The garbage in Providence has been disposed of in this way very economically and with entire satisfaction for a great many years. On the other hand, within a year or two, a grand jury investigation of the piggery at Los Angeles, where the city's garbage is taken, resulted in the condemning of that method of disposal. They found that something like 20% of the pigs were tubercular and that fully half of those were tubercular in such form that they passed through the Government examination and got on to the market. On that account, and on account of the general sanitary conditions at the time of the investigation, they condemned the method. There is a piggery at Grand Rapids, which I have not seen, but at which I understand the garbage is first sterilized before it is fed to the pigs, and if it is used only as a base, being enriched afterwards with proper food, that would seem to make the method a safe one. At most places I suppose it is a question of the care and efficiency of the operation. The method has its advantages from a money point of view.

FURNACE EFFICIENCY

Joseph Harrington, M. W. S. E.

Presented September 23, 1912.

ABSTRACT OF PAPER.

1. Furnace efficiency is the controlling factor in combined efficiency.
2. A heat balance on the basis of coal as fired is necessary for the complete understanding of efficiency losses.
3. Furnace efficiency is the key to high boiler-room economy.
4. Furnace efficiency is independent of the rate of combustion.
5. A horizontal combined efficiency curve is possible of approximate attainment.

The code of the American Society of Mechanical Engineers specifies the combined efficiency of a boiler and grate as being the ratio of the heat actually used in converting water into steam, to the total amount of the heat energy in a unit of dry coal, and, until recently, combined efficiency has been the basis for judging the performance of a boiler and furnace.

It is for the purpose of illustrating the insufficiency of that kind of an analysis that this paper has been written. Furthermore, it is desired to present a refinement of this method by which the efficiency of the elements themselves can be determined, and to discover and correct errors leading to low combined efficiency.

The development of the modern mechanical stoker has resulted in an improvement in steam generation, so that the process of burning coal is considered now the more delicate and important of the elements entering into the stoker-boiler unit. An inspection of the heat balance under the heading of *Boiler Losses*, in the test record sheet of the Green Engineering Company, will show three items. No. 61 is the heat loss due to the temperature of the gas above the temperature corresponding to the steam pressure. A study of Fig. 1 will show the rise in flue temperature corresponding to an increased boiler capacity. Inasmuch as the steam pressure was constant throughout these tests, the abscissae may be taken as indicating the rate of combustion. If documentary evidence is required. this will show that the rise in flue temperature is not proportional to the rate of combustion, or the developed capacity of the boiler. The significance of this is that the true boiler efficiency is not greatly affected by differences in the rate of heat absorption. Ability to absorb heat is the fact controlling boiler efficiency, while, as I will try to present later, furnace efficiency is affected by several considerations. I think there is no question but that the ability of a tube to transmit heat, when in a standard condition of cleanliness, is practically the same at all times under similar conditions.

Herewith is shown a table (Fig. 2) of half a dozen heat balances, which will indicate a fairly constant boiler efficiency at a fair range of ratings. The grate and furnace efficiency, however,

vary to an appreciable extent, which seems to bear out the statement of the sensitiveness of furnace efficiency, and the necessity for the closest watching to secure the highest results.

A given weight of coal per square foot may be burned under widely varying furnace efficiencies, but the boiler efficiency that goes with it is not affected to a corresponding extent.

It is in the furnace that lie the greater possibilities of either high or low efficiency, and it becomes doubly important, therefore, that we develop a means whereby this part of the process may be segregated and analyzed.

It has been my object, of late, to develop these means or methods of analysis so that they can be practically applied to the testing of the stoker-boiler unit without undue necessity for impractical refinement or the use of laboratory apparatus. My study of

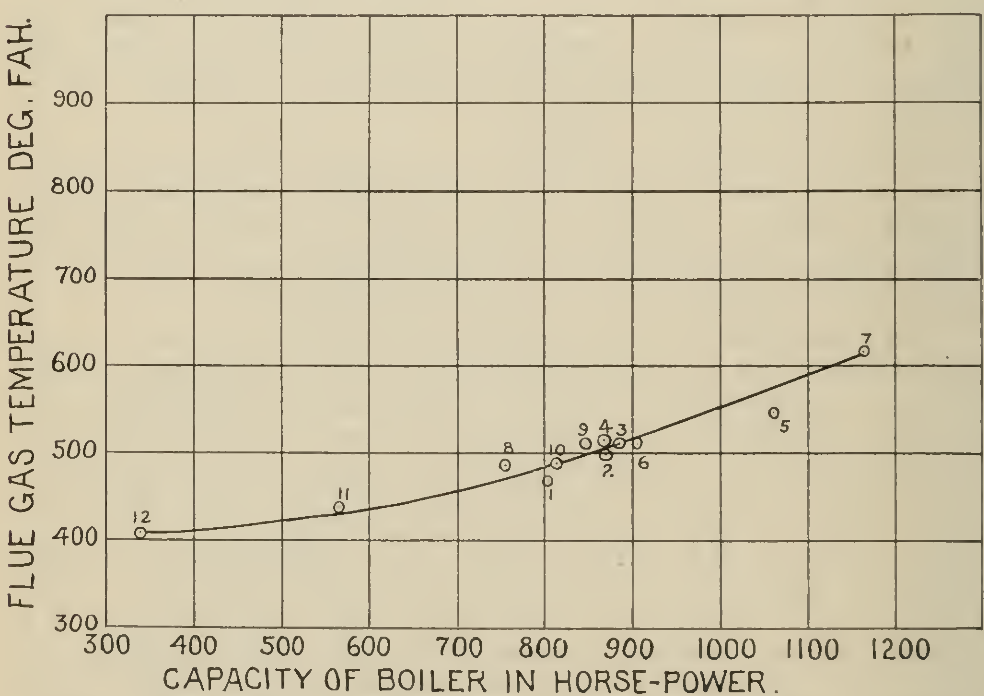


Fig. 1. The relation between boiler capacity and the flue temperature.

this problem has resulted in some very interesting figures regarding the possible efficiencies of the furnace, and I will present a few such illustrations for your consideration.

For a proper appreciation of the disposition of the heat contained in a pound of fuel, the only logical way to base this analysis is on the heat contained in the fuel as it is actually fired, rather than upon the basis of either dry coal or combustible, which, after all, are theoretical conditions and are never attained in actual practice. What the engineer wants to know is how the heat contained in the actual coal he is firing is disposed of; and as the moisture contained in the coal has an influence on the efficiency of the entire

	HEAT BALANCE PER POUND OF COAL FIRED—B.T.U.																		
	B.T.U. PER POUND	ABSORBED BY BOILER		NECESSARY LOSSES				FURNACE & GRATE LOSSES						BOILER LOSSES					
		WATER	STEAM	MOISTURE & H_2O FROM H	BY DRY GASES UP TO TEMP.	AVAILABLE FOR UNIT	HIGHEST THEOR EFF'CY	COMB. IN ASH	EXCESS AIR TO T.P.	CO	CINDERS	AVAILABLE FOR BOILER	FURNACE & GRATE EFF'CY	BY TEMP. GASES ABOVE T.P.	AIR LEAKAGE	RADIATION & UNACC'T FOR	BOILER EFF'CY.	COMB. EFF CY.
JULY 6, 1911	11027	9534	865	391	655	12981	92.6	319	89	0	290	12283	94.6	483	854	546	84.7	74.1
JAN. 18, 1912	13092	8668	765	450	696	11946	91.3	405	193	56	190	11102	92.9	941	406	322	84.9	72.0
JUNE 1, 1911	14103	9089	831	447	713	12943	91 8	332	523	155	290	11643	90.0	660	311	732	85.2	70.3
MAY 31, 1911	13389	8557	803	427	667	12295	91.8	557	339	121	290	10888	89.4	576	196	856	85.2	69.9
JUNE 15, 1911	13370	8671	749	471	624	12275	91 8	479	460	0	290	11046	90.0	658	273	695	85.2	70.4
JAN. 29, 1912	13362	8706	734	487	707	12168	91.1	594	175	110	290	10999	90.4	424	349	786	85.9	70.7
	HEAT BALANCE IN PERCENT.																	
JULY 6, 1911								2.39	0.64	0.0	2.08		94.6	3.47	6.13	3.92	84.7	74.1
JAN 18, 1912								3.09	1.47	0.43	1.45		92 9	7.19	3.10	2.46	84.9	72.0
JUNE 1, 1911								2.35	3.71	1.10	2.06		90.0	4.82	2.21	5.19	85.2	70.3
MAY 31, 1912								4.16	2.53	0.90	2.17		89.4	4.30	1.46	6.39	85.2	69.9
JUNE 15, 1911								3.58	3.43	0.0	2.17		90.0	4.90	2.04	5.20	85 2	70.4
JAN. 29, 1912								4.45	1.31	0.82	2.17		90.4	3.17	2.61	6.88	85.9	70.7

Fig. 2. Some Heat Balances.

process, it must be taken into consideration in an accurate analysis.

The middle western coals will frequently contain as high as 15% of moisture, and lignites almost invariably carry from 25% to 40%. In the latter case, a considerable portion of the total heat value of the coal is utilized in evaporating this moisture, which, of course, robs the boiler of just that much heat and reduces the net evaporation by that amount. If a prediction of the evaporative value of a lignite coal was made, based on the heat value of that coal dry, the inaccuracy will be clearly observed in the analyses of heat values of moist coal, which are given in connection with this paper. The case of the middle western coal is similar, although to not quite the same extent. Eastern coals exhibit the more accurate relation between the actual and dry analyses, but boiler tests with these coals should be analyzed on a basis of coal as fired just the same.

In this connection, as a basis of study I refer to the test sheet, Fig. 3, which has been developed by the Green Engineering Company for recording their tests, and which takes into account the heat balance based on coal as fired, in which the actual heat in a pound of fuel is accounted for, the various losses being given in terms of British thermal units. An expression of these values in the form of percentages might be preferable to those not accustomed to judging heat losses in terms of actual B. t. u. by giving a clearer notion of the significance of the item. This test sheet has been developed in logical order, so that the various items can be figured in rotation, the data for the calculation of every item having been previously figured. In this way it is easy to figure a boiler test in an hour, and robs the calculations of much of their mystery and difficulty.

On account of the heat balances involving the ultimate analysis, some question may be raised as to the difficulty of obtaining this analysis in connection with an ordinary test. If the test is to be worked out in all its refinements, such analysis is, of course, essential, but it has been found that with a given coal, the ultimate analysis is so nearly constant that the heat balance is not affected materially by the slight variations that exist.

If the exact origin of the coal can be established, an ultimate analysis can be easily determined. The United States Geological Survey has published a great many such analyses, identifying each analysis with a certain coal. To facilitate the use of these test sheets, it is the intention of the writer to eventually tabulate all of the existing ultimate analyses that are available, in the hope that a sufficiently close identification may be made, so that it will only be necessary to determine the exact origin of the fuel to find an ultimate analysis that will very closely correspond.

In Fig. 4 is shown the effect of moisture in the coal as it affects the heat available for useful work. This is plotted on the follow-

ing assumption: that the net coal in a pound of fuel (disregarding ash for the time being, or considering the ash percent constant) is the difference between the percentage of moisture and 100. For example, wet coal containing 20% of moisture would contain only 80% of combustible. In this way, the diagram has been worked out within the range of ordinary moisture content.

In lignite coals, we frequently encounter 35% moisture, which would mean 9,350 B. t. u., instead of 15,000 if the coal had not contained any moisture.

As a matter of interest, Fig. 5 has been worked out carrying it to the ultimate, wherein it is shown that if coal contained 93% of moisture, it would take all of the remaining combustible to evaporate its moisture content. In other words, there would be no heat left for external work.

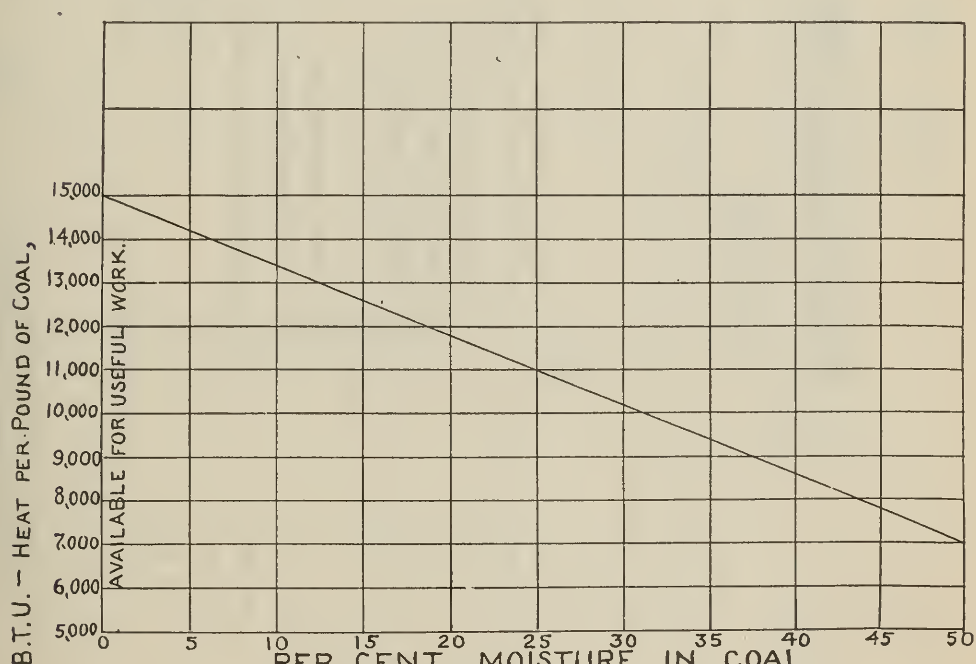


Fig. 4. Influence of Moisture in Coal, on Heat Available for Useful Work.

When other unavoidable losses are considered which are necessarily encountered in practice, this result is not so far from being a possibility. Add to the losses due to the moisture contained, the unavoidable losses due to combustible in refuse, the losses due to excess air, the losses due to radiation and unaccounted for, and the other losses which may be charged against the particular method of operation in vogue, and a point will very soon be reached where a wet coal ceases to be of any value. We have found by experimentation that a moisture content of 25% is about the limit of practical usefulness with the ordinary form of furnace in commercial service.

Lignites carrying moisture in excess of this, require a specially

Report of Test on ________ Boilers Equipped With ________

Grates at ________ Owned by ________

Purpose of Test ________

Fired by ________ of ________ Date ______ 19 ____

1	Run from .... to		11	Steam gauge pressure .... lbs.	
2	Duration of test		12	Atmospheric pressure .... lbs.	
3	No. of boilers used		13	Absolute steam pressure .... lbs.	
4	Type of boiler		14	Draft suction at uptake .... inches	
5	No. of tubes		15	Draft suction over fire .... inches	
6	Diameter of tubes		16	Draft pressure under fire .... inches	
7	Water Heating surface .... Sq. Ft.		17	Average temperature boiler room .... °F	
8	Superheating surface .... Sq. Ft.		18	" " flue gases .... °F	
9	Grate surface .... Sq. Ft.		19	" " feed water .... °F	
10	Ratio grate surface to water heating surface .... 1 to		20	" " steam Tp .... Ts .... °F	

21 Name of fuel ....

22 Size of fuel ....

PROXIMATE ANALYSIS						ULTIMATE ANALYSIS			ASH		FLUE GAS			
H2O	V.M.	F.C.	Ash	S	Btu. Per Pound	C.	H.	S.	% Comb. in Refuse	Refuse % Coal Fired	CO2	O	CO	N. etc
					Fired .... Dry Comb.					Refuse %	1st Pass			

25	Coal burned per hour dry .... lbs.	
26	Coal burned per hour per sq. ft. grate surface actual .... lbs.	
27	Total weight of refuse .... lbs.	
28	Total weight of combustible .... lbs.	
29	Water evap. total run actual .... lbs.	
30	" " per hour actual .... lbs.	
31	Factor of evaporation	
32	Water evaporated per hour (f. & a 212 deg.) .... lbs.	
33	Quality of steam .... %	
34	Horse power builder's rating	
35	Boiler horse power (Mean of Test)	
36	" " " (Max. hr.)	
37	Per cent. rating (Mean of Test)	
38	Sq. ft. water heating surface per h.p. (Mean of Test)	
39	Water evaporated actual per lb. coal as fired .... lbs.	
40	" " " " " dry coal .... lbs.	
41	" " f & a 212 deg. per lb. coal as fired .... lbs.	
42	" " f & a 212 deg. per lb. dry coal .... lbs.	
43	" " f & a 212 deg. per lb. combustible .... lbs.	
44	Wt of gas per lb. Coal Fce. .... lbs. Flue .... lbs.	
45	Percentage of excess air " .... % " .... %	
46	Cinders, (a) weight .... (b) % coal fired	
47	Carbon in Cinders per cent coal fired .... %	

	Heat per lb. Coal fired .... Btu	
49	" absorbed by water in boiler .... Btu	
50	" " " steam " " (superheat) .... Btu	
	NECESSARY LOSSES	
51	Heat absorbed by moisture & H2O from burned H up to Tp .... Btu	
52	" " " Theoretical Amt. dry gases up to Tp .... Btu	
53	" available for Unit .... Btu	
54	Highest Theoretical Efficiency .... %	
	FURNACE AND GRATE LOSSES	
55	Heat loss due to combustible in ash .... Btu	
56	" absorbed by excess air up to Tp .... Btu	
57	" loss due to production of C O .... Btu	
58	" " " " " " Cinders .... Btu	
59	" available for Boiler .... Btu	
60	Furnace and grate efficiency .... %	
	BOILER LOSSES	
61	Heat loss due to temp. of gasses above Tp .... Btu	
62	" " " " air leakage through Boiler Setting .... Btu	
63	" " " " Radiation and unaccounted for .... Btu	
64	Boiler Efficiency .... %	
65	Combined Efficiency .... %	

Ta = Temp. of air in boiler room.
Tp = Temp. corresponding to steam pressure.
Tf = Temp. of gases in flue.
Cb = Carbon burned per lb. actual coal

Sp. Ht. = Specific heat of the steam.
Ts = Temp. of steam as superheated.
Hs = Total heat in superheated steam.
Ht = Total heat in dry steam at observed pressure.

Green Engineering Co., Chicago, Ill.

designed furnace, wherein the heat generated by the combustion of the fixed carbon can be more efficiently brought into contact with the incoming fuel. Inasmuch as this is not a very practical possibility in the furnace, it brings up the question of pre-drying these fuels with the chimney gases, and the writer has in course of preparation a design suitable for this work.

The entire operation must be considered in a study of the efficiency problem, inasmuch as the heat taken from the waste gases for the drying of the fuel necessitates either an excessively high stack or some form of induced draft. In either event, the coal must furnish the energy for its own preparation and drying, and the furnace efficiency in this case must be extended to include any such preparatory zone.

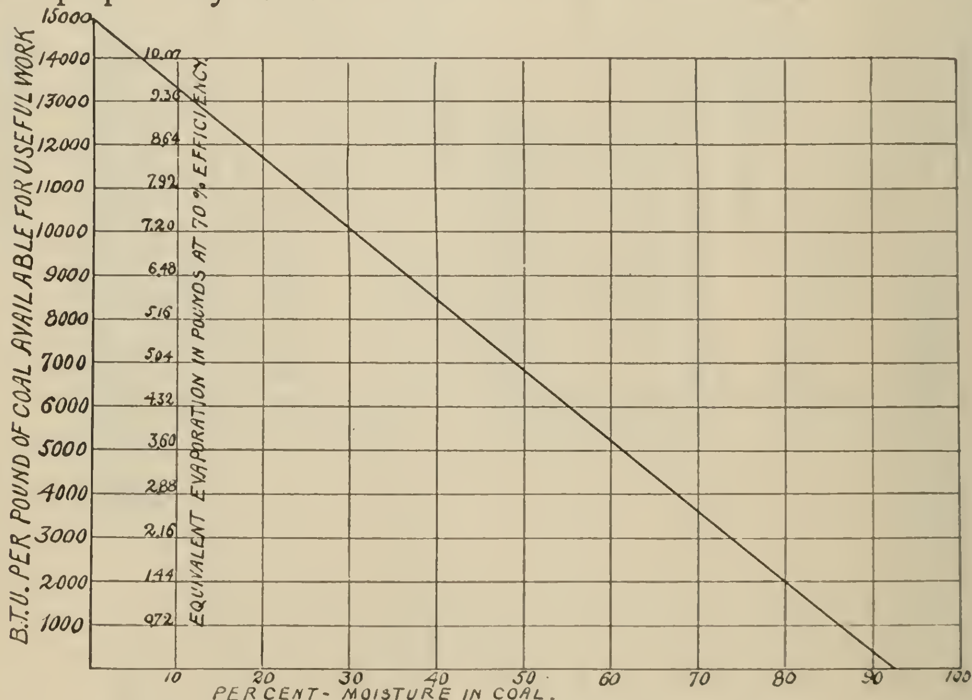


Fig. 5. Influence of Moisture in Coal on Evaporative Power of the Fuel.

In addition to the influence of moisture, furnace efficiency is affected by the amount of air used in burning the fuel. In many cases with western fuels, a gas analysis of 10% of CO_2 would be considered fair practice. To maintain this figure, a fairly uniform fuel bed is required, and there must not be frequent or extensive opening of firing doors for stoking or slicing. A gas analysis of 13% of CO_2 is about the limit of economical operation with western coals, because when the CO_2 is carried much beyond this point, CO will develop and the furnace efficiency on this account will not increase, the loss due to imperfect combustion being greater than the gain effected by reducing the excess air. A study of these various effects is given in Figs. 6, 7 and 8.

In Fig. 6 we note the effect on furnace efficiency of an excess of air. This curve has been carried to the ordinary extent of dilution, and illustrates the result of a leaky fuel bed or porous setting. Figure 7 has been carried out to the extreme, merely as an interesting example, and from this curve it will be noted that if the furnace gases could be diluted to 1,800% in excess of theoretical requirements, the efficiency would be zero. In other words, all the heat in the coal would be absorbed by the air without an appreciable rise in temperature.

In the curve, Fig. 8, is shown the effect of varying steam pressure on the relation between furnace efficiency and excess air. This

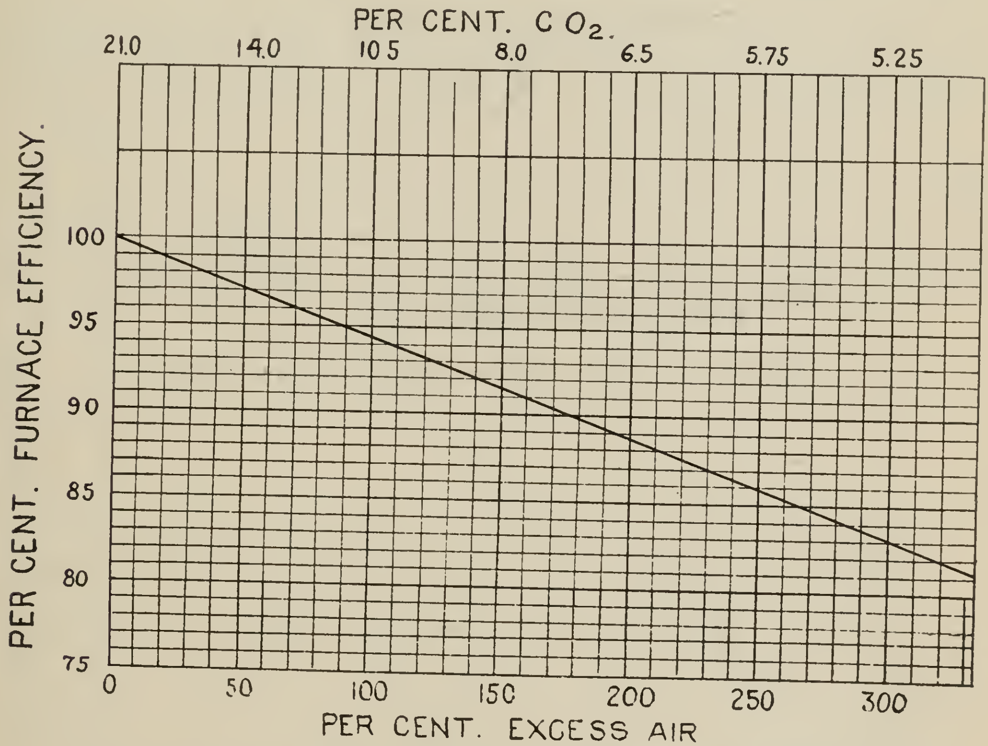


Fig. 6. Relation Between Furnace Efficiency and Excess Air.

is not materially important, but it is interesting to note that the lower the steam pressure, the less is the detrimental effect of excess air.

The design of the furnace to effect the necessary mixing, varies widely with different fuels and drafts and rates of combustion, and in the absence of any means for determining this mathematically, it appears to still remain largely a question of experience.

The product of incomplete combustion is CO, wherein only about one-third of the potential heat is developed. It is, therefore, obviously important that CO must not be present in appreciable amounts.

It has been stated that there are other hydro-carbon compounds

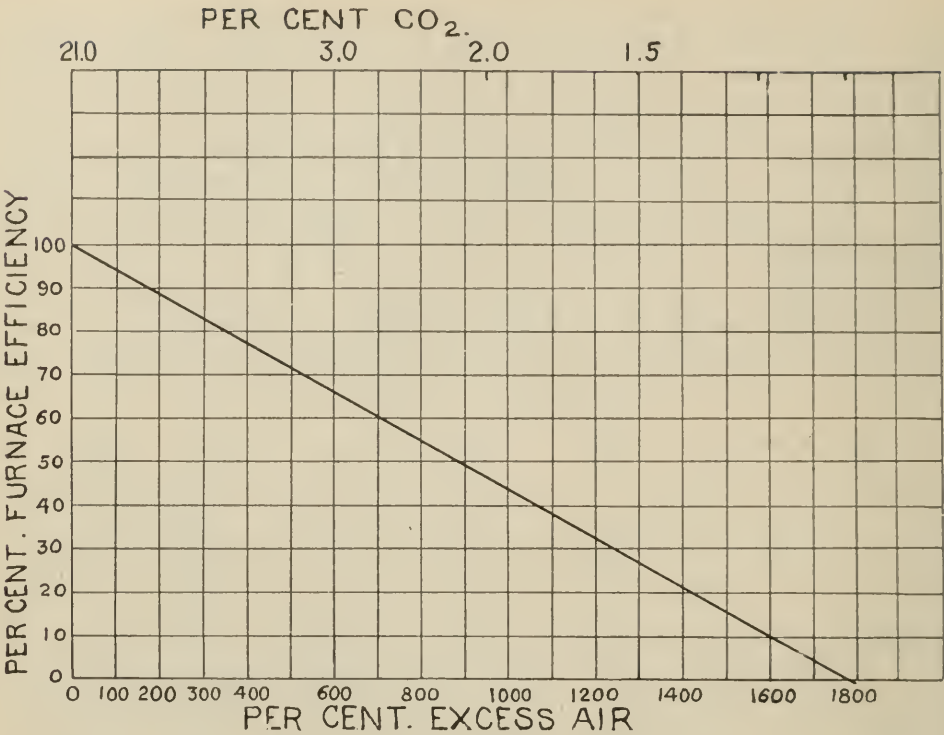


Fig. 7. Relation Between Furnace Efficiency and Excess Air.

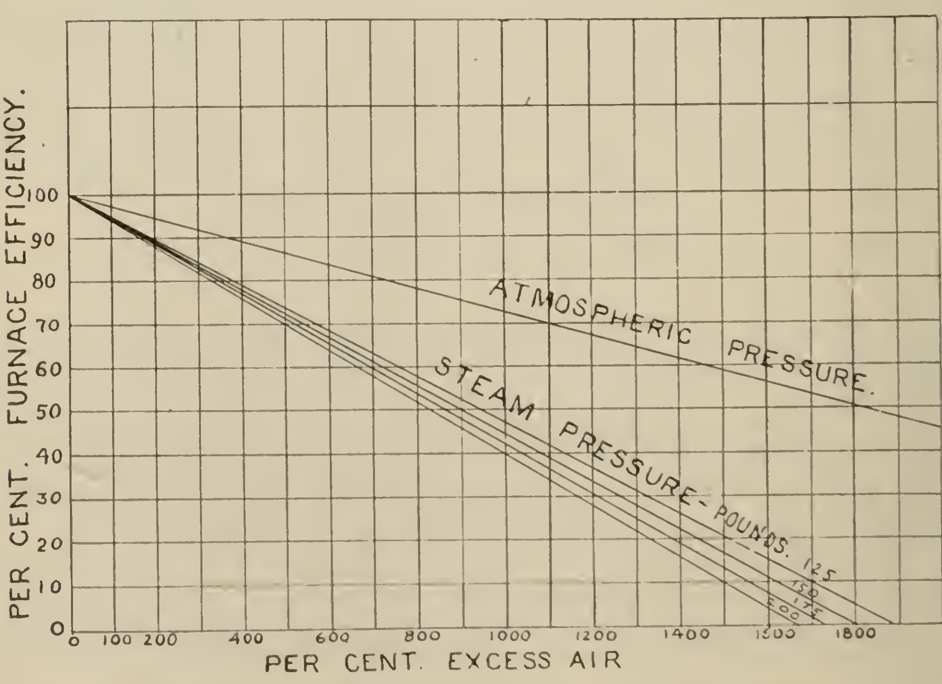


Fig. 8. Relation Between Furnace Efficiency and Excess Air.

which are present in flue gases and which are carried away with the escaping gases whenever CO is present. These gases, not being of such a nature as to render it possible to detect them by the usual means, have added an element of uncertainty in the ultimate analysis of efficiency losses.

My experience, in analyzing a large number of heat balances, is that the presence of these intangible combustible compounds is quite apparent. A portion of the heat unaccounted for is undoubtedly due to this. It is doubly important, therefore, that CO in furnace gases should be held down to an absolute minimum. It is not always the case that heavy reduction in air excess must be secured before CO will appear. This is largely a question of the proper mixing in the furnace which is dependent on the size and design of the combustion space. Both CO and excess air may be

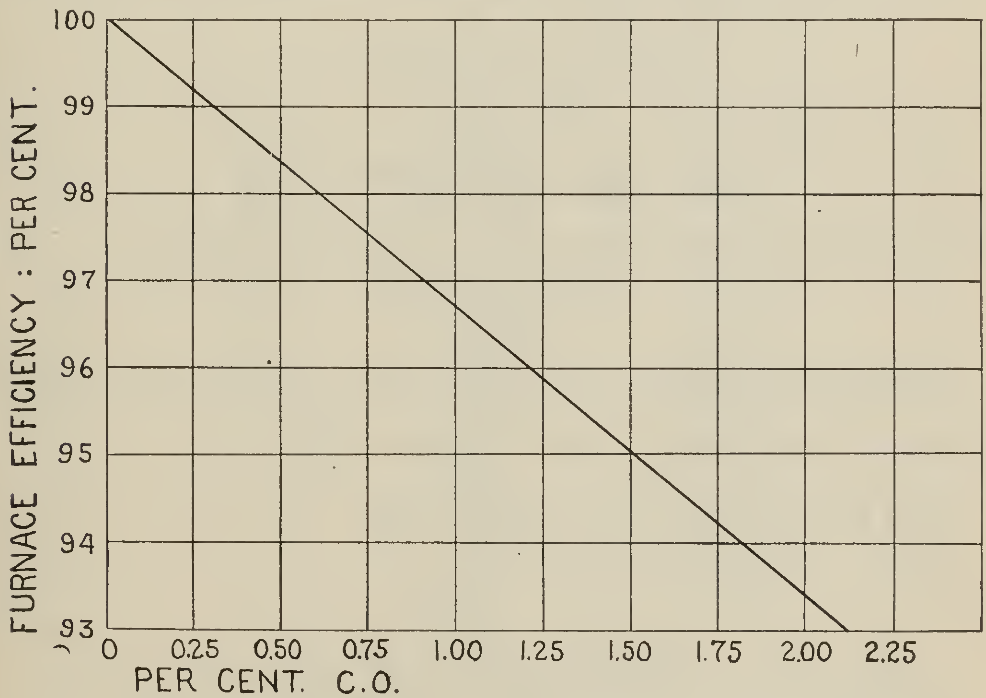


Fig. 9. Relation Between Furnace Efficiency and Loss of C. O.

present at once and the extent of this, as above stated, is purely a question of the capacity of the furnace to mix and retain the gases until the combustion is complete. It is, however, our experience that when CO appears, it is time to stop the reduction of air supply, even though it is quite obvious that the mixing ability of the furnace is deficient. Figure 9 illustrates the effect of CO on furnace efficiency.

I give, in this connection, the mathematics which show the method of determining the equation of both of these curves. The deduction therefrom is that each 1% of CO reduces furnace effi-

ciency by 3 1/3%, and if this were carried to the ultimate, the efficiency would be zero when the percent of CO reached 30, assuming that such were possible.

Item 56. Heat absorbed by excess air up to Tp

$$= \frac{11\ CO_2 + 8\ O + 7\ (CO + N)}{3\ (CO_2 + CO)} \times Cb \times 0.24\ (Tp - Ta) - \text{item } 52$$

For steam at 150 lb. pressure $Tp = 366$ deg. Fah.

assume $Ta = 70$ deg. Fah.

Using completely-burned carbon at 14.500 B. t. u. per lb. $Cb = 1$

then item $52 = 3.05\ (366 - 70) = 903.$ B. t. u. a constant

and $0.24\ (Tp - Ta) = 71.04$ a constant

Assuming that air for combustion is 21% oxygen and 79% nitrogen, for the present case $(CO + N) = 79$

$O = 21 - \%\ CO_2$ and $3(CO_2 + CO)$ becomes $3CO_2$.

Item 56 then reduces to

$$71.04\ \frac{(CO_2 + 240.3)}{CO_2} - 903\ \text{B. t. u.}$$

The net heat available for the boiler is

$$14{,}500 - \left[71.04\left(\frac{CO_2 + 240.3 - 903}{CO_2}\right)\right]$$

and the efficiency is equal to this expression divided by 14,500, or

$$\frac{15332\ CO_2 - 17072}{14500\ CO_2}$$

Putting this in equation with efficiency $= E'$ and percent $CO_2 = P'$, and reducing in lowest terms, we have $E' = 1.057 - \frac{1.177}{P'}$.

Each 100% excess air affects efficiency 5.62%.

Item 57. Heat loss due to production of CO.

$$\frac{CO}{CO + CO_2} \times 10150 \times Cb$$

Assume air $= 79\%$ nitrogen, then $CO + CO_2 = 21\%$.

Using pure carbon $Cb = 1$ and B. t. u. value per lb. is 14,500.

Then loss $= \frac{10150\ CO}{21}$

Net heat available for the boiler per lb. of carbon

$$14500 - \frac{10150\ CO}{21} = \frac{304500 - 10150\ CO}{21}$$

$$\text{Efficiency} = \frac{\text{net heat}}{14500} = \frac{\dfrac{304500 - 10150\ CO}{21}}{14500} = 1 - \frac{CO}{30}$$

If $E =$ efficiency and $P =$ percent CO

Then the above equation may be written

$$E = 1 - \frac{P}{30}$$

which reduces to $30\ E + P = 30$.

Using per cent efficiency as ordinates and per cent CO as abscissae, this equation is a straight line cutting the E axis at 100% and the P axis at 30%. *Each 1% CO affects furnace efficiency 3⅓%.*

Tabulation of efficiencies with varying percentages of excess air.

Assume that air is 21% oxygen and 79% nitrogen.

$$\text{Percentage excess air} = \frac{21 - \%\ CO_2}{\%\ CO_2}$$

or, transposing to get CO_2 for a desired per cent excess, we get

$$\text{Per cent } CO_2 = \frac{21}{1 + \dfrac{\%\ \text{excess air}}{100}}$$

Per cent Excess.	Per cent CO_2.	Heat Absorbed by Excess Air up to Tp B. t. u.	14,500 Minus Loss.	Per cent Efficiency.
10	19.1	61.38	14438	99
40	15.0	306.3	14194	98
70	12.35	553.52	13947	96.3
100	10.5	795.0	13705	94.4
150	8.0	1299.4	13201	91.0
200	6.5	1796.7	12703	87.6
250	5.75	2137.7	12362	85.3
300	5.25	2417.	12083	83.3
425	4.00	3430.	11070	76.4
600	3.00	4851.	9649	66.5
950	2.00	7702.	6798	46.8
1300	1.5	10547.	3453	23.8
1575	1.25	12797.	1703	11.7
1780	1.12	14400.	....	.0

Other assumptions upon which table is based:

Tp = 366 deg. Fah. = temp. at 150 lb. gauge.
Ta = 70 deg. Fah.

CALCULATION OF THEORETICAL MAXIMUM COMBINED EFFICIENCY BASED ON 150 LB. STEAM PRESSURE AND 70 DEG. FAH. TEMPERATURE OF AIR.

Item 51 = loss due to heat absorbed by moisture and H_2O from burned hydrogen up to Tp.

$$\frac{H_2O + 9\ H}{100} \times (212 - Ta) + 970.4 + 0.50\ \ (tp - 212)$$

Assume an ultimate analysis $H = 3.88\%$ $H_2O = 3.2\%$

$$\frac{3.2 + 34.92}{100} \times (212 - 70) + 970.4 + 0.50\ \ (366 - 212)$$

$$.3812 \times 1189.4 = 453\ \text{B. t. u.}$$

Item $52 = 3.05\ (Tp - Ta) = 903$ B. t. u., which is heat absorbed by theoretical amount of dry gases up to Tp.

Sum of losses 51 and $52 = 1356$ B. t. u.

Net heat available for the unit $= 14500 - 1356 = 13144$ B. t. u. and highest theoretical efficiency $= \dfrac{13144}{14500} = 90.6\%$.

This loss is independent of rate of combustion.

When the higher grade eastern coals are properly prepared for combustion, a much greater degree of oxygen absorption can be attained. With an incandescent bed of coke 12 or 15 in. in thickness, almost all of the oxygen in the air entering the furnace for combustion purposes may be removed. To quote my own experience with our coking coal type of chain grate, a gas analysis of 18% may be obtained, and 16% or 17% is of daily occurrence, without the presence of more than a trace of CO. This is due primarily to the nature and thickness of the fuel bed, the porosity of the bed in the case of the eastern coals lending itself better to the carrying of a heavy fire than is the case with free burning coal. The latter acts on the grate surface like a layer of earth, and it is not possible to draw air through it with the same facility as in the case of coke. It is, therefore, the practice to carry much thinner fires, where holes more readily form and where the short circuiting is more marked, due to the tightness of the rest of the bed.

It is perhaps necessary here to refer to the coking coal chain grate a little in detail to understand more clearly the above references. This is, in brief, a chain grate stoker (Fig. 10) fitted with an inclined coking surface between the hopper and the moving grate. The fuel is fed to the top of this incline, over which it gradually descends toward the grate surface while undergoing the process of coking. The volatile constituents are eliminated on this incline to such an extent that there remains no further tendency to form coke after the horizontal grate surface is reached. The agitation of the fuel bed prevents the formation of the cake, which is characteristic of these fuels when subjected to heat. The coked coal reaches the chain grate surface in a fragmentary condition, and the resultant fuel bed is, of necessity, open and porous. When in this condition, it will burn out quietly to a finish practically the same as in the case of a thoroughly ignited free burning coal.

The travel of the fuel over the incline is affected primarily by gravity, the fuel sliding down as the chain carries away the fuel at the base of the incline. In order that there could be no doubt as to the sufficiency of the agitation, the incline is constructed of two transverse plates, one of which is automatically caused to vibrate through about 5° or 10° of arc, giving a slight motion to the fuel, but not sufficient to cause it to avalanche or become mixed up in a manner which will cause the clinkering or balling up of the fuel bed, even under the highest rates of combustion. It was found,

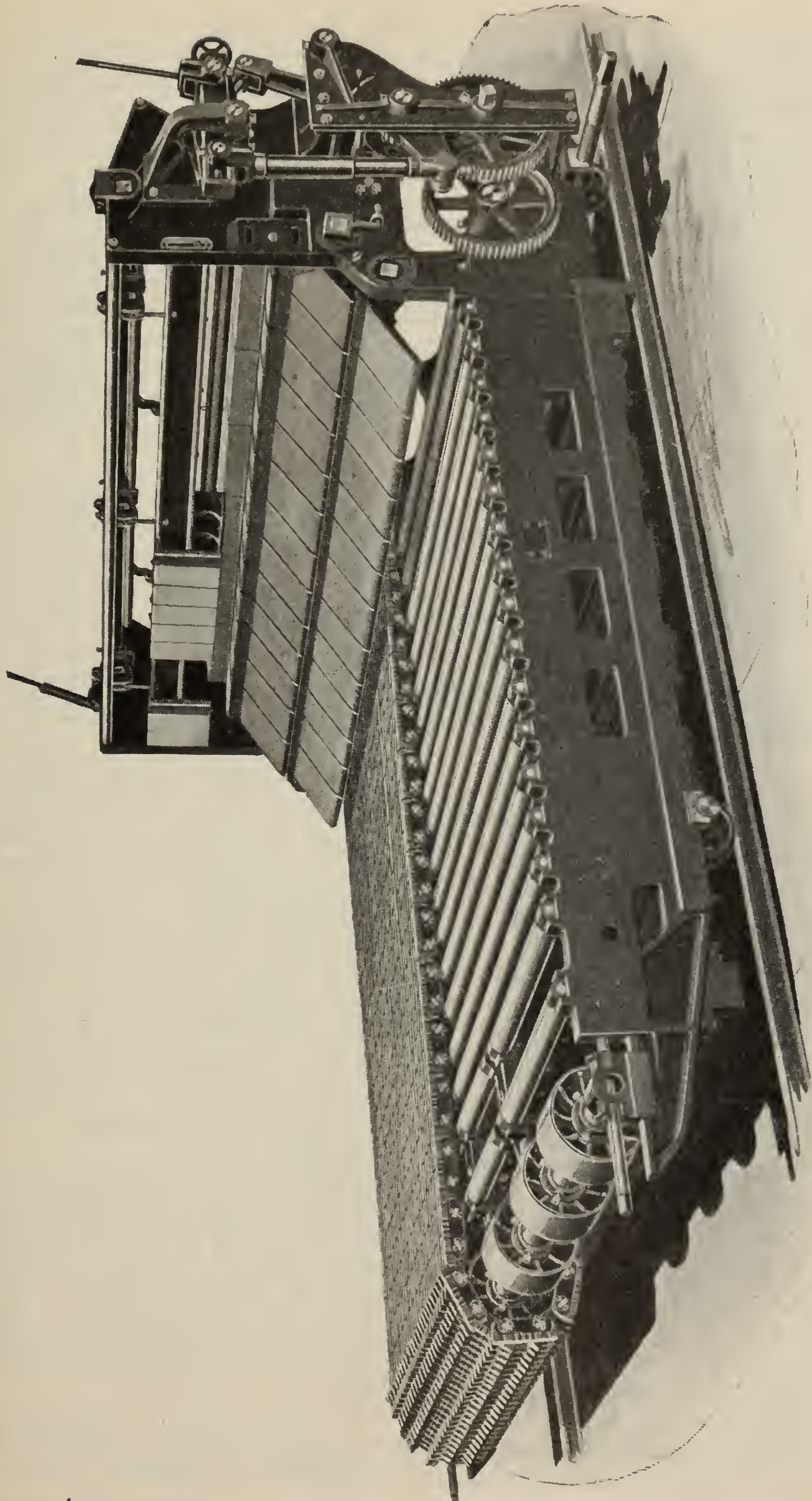


Fig. 10. The Green Coking Chain Grate Stoker.

after numerous experiments, that a very slight agitation was sufficient, if applied at just the right time and in a continuous manner. It was furthermore determined that the distillation of the binding substance was affected within the first 30 in. of travel of the fuel. The incline and the agitation thereof were then so proportioned as to meet these requirements.

The inclined surface is made without ventilation, as it is desired that the fuel should absorb heat as rapidly as possible during this period. Ventilation at this point would retard this absorption of heat and delay the process of distillation of the bituminous binder. It is noted in practice that the fuel is incandescent just about at the foot of the incline, after which time there can be no further distillation of volatile combustible. From that point on, the fixed carbon, in the form of finely divided particles of coke, burns quietly to a finish.

A further advantage of this form of agitation lies in the fact that it is slight but continuous, which prevents the forming of large lumps of coke that would occur if the agitation were infrequent and great, as is the case with slicing by hand or equivalent mechanical operation. The fuel is divided into small pieces, which permits of a uniform fuel distribution, the prevention of holes in the fire, the accomplishment of uniform termination of combustion, and consequent prevention of air leaks through the fire or at the end of the stoker.

The ignition of this fuel is not the most difficult task, as it is always rich and gives off intense heat. The ignition is affected by means of the usual flat ignition arch placed horizontally, or inclined above the grate surface. The design of this igniting arch is varied according to the requirements of the particular fuel.

The design of the coking coal chain grate, type *L*, is not such that it requires to be finely adjusted to any particular grade of fuel, inasmuch as coals varying widely in their volatile constituents can be burned with equal success. Coal can be burned with 40% of volatile, quite as readily as coals with 15% of volatile, so that the purchaser does not have to worry about getting exactly the same grade of coal when using this stoker. This is of considerable practical value where the coal market is variable.

Figure 11 shows the theoretical efficiency of a furnace and boiler, by which is meant the combustion of a pound of coal minus only those losses which are absolutely necessary in the present state of the art. These necessary losses are items Nos. 51 and 52, of the Green Engineering Company's test sheet, all being based on the exact amount of air required for complete combustion, with no ash pit loss and a boiler efficiency of 100% (i. e., no loss for items Nos. 61, 62 and 63).

This is plotted on a capacity basis, and gives us a standard at which we may aim in our attempts to improve the furnace efficiency

under commercial conditions. You will note the fact that the efficiency is absolutely independent of the rate of combustion, which is not only theoretically correct but it is a practical condition very greatly to be desired, as it opens up a vista of possible plant efficiencies that is startling in its magnitude.

For comparative purposes, Fig. 11 also shows another curve which illustrates the actual combined efficiencies that have been obtained with the Green chain grate under a fourteen high B. & W. boiler, using West Virginia coking coals of about 14,500 B. t. u. The same kind of curve taken from Kent's *"Steam Boiler Economy,"* page 223, curve $f = 25$, is shown, and right here I desire to lay greatest stress on the significance of these curves from the standpoint of boiler room economy.

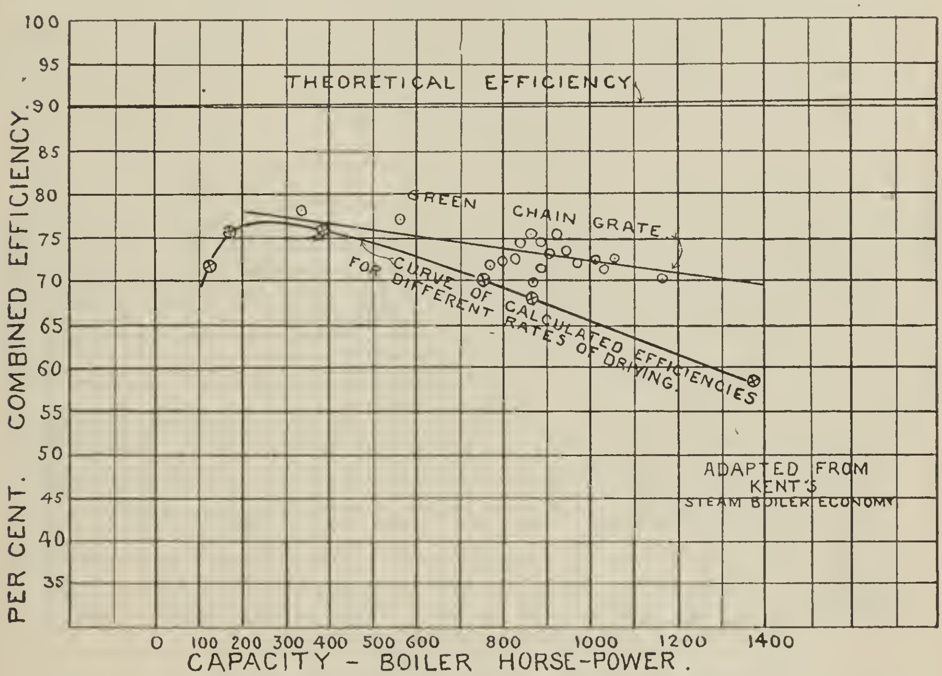


Fig. 11. Curves of Calculated Efficiency, Furnace and Boiler Combined.

Outside of the question of a high versus a low efficiency, the matter of a horizontal efficiency is of greatest importance. There is no single question entering into the production of a satisfactory plant efficiency that is anything like the importance of a uniform efficiency curve. In practically all power plants, the load is variable, and in the case of street railway and illuminating companies, the load is extremely uneven with sudden and high peaks, and in many cases, unexpected peaks.

With the method in vogue which is most universally practiced at present, the fluctuations are taken care of by putting boilers on or off the line, with intervals of banking periods between the peaks. It is customary to carry a number of boilers in bank, warming

them up in time to have them steaming by the time the load increases, and putting them on the line successively, in sufficient numbers to provide the required steam.

The plant formed of individual units having a very peaked efficiency curve, could only be operated at the rating corresponding to its maximum unit efficiency, or the efficiency of the entire plant would be reduced.

It was considered that the losses due to banking a boiler were not as great as those suffered from operating at a point considerably below rating, so that extremely variable loads necessitated a constant banking and breaking of banks throughout the day. There is no question that under certain circumstances this method is

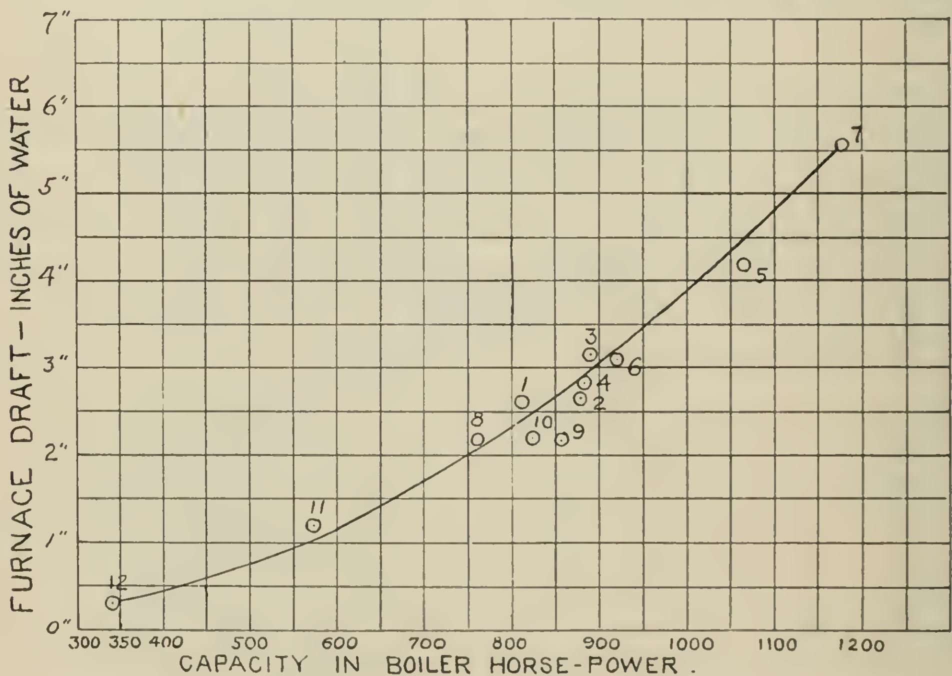


Fig. 12. Relation Between Boiler Capacity and Furnace Draft.

preferable, because of the heavy dip in the efficiency curve as it has heretofore been developed. The losses due to the banking period are invariably heavy, and there is no practical way of eliminating them. In the case of an illuminating company, where a sudden thunder storm may double their load almost instantly, it is not practical to carry even banked fire, but spread fires must be maintained. This makes the losses even greater, and in a large plant the total of such losses reaches an immense sum.

The curves shown herewith, illustrating the practically horizontal efficiency with the Green chain grate, compelled a complete revamping of our ideas in regard to carrying of fluctuating loads.

With the tremendous advantage which this affords, the operating engineer having a load represented by a certain number of

boilers at, say, 300 h. p., each minimum load during the early morning hours and an afternoon peak of 1,000 h. p. for the same number of boilers, can carry the load throughout the 24 hours with this number of boilers rated at 500 h. p., and equipped with stokers. Inasmuch as Fig. 12 shows the variation in the rate of steaming, it is only necessary to figure the draft required to develop 300 and 1,000 h. p., respectively, and provide means for the ready development of this draft.

The 500 h. p. boiler, by checking the draft sufficiently, will thus deliver 300 h. p. or 1,000 h. p. at will, and the owner does not sacrifice anything in the way of efficiency in order to accomplish this variation. The problem of a large electric service company or manufacturing plant, is but this problem magnified with savings in coal in proportion to its size.

I desire to give due credit to my assistants, Messrs. T. A. Marsh and T. A. Peebles, for valuable help in connection with this paper.

Discussion.

A. Bement, M. W. S. E. (Chairman): In legendary history there is a story of two knights on a road who approached a sign or emblem from different directions. One read it and announced to the other what he had read; the other read it as he saw it, and declared it to be something quite different. They disputed the proposition, and the dispute terminated in a fight. While thus engaged, somebody came along and said, "What is the matter? Why are you fighting?" and they explained. Then the stranger looked at the emblem on both sides, and found that it was different on the two sides. Each knight had seen one side of the emblem only. This legend is somewhat like the problem we have tonight; we are inclined to look at the matter from different standpoints, and also have treated it in different ways. Sometimes one is thinking about the boiler when he runs a "test," and if the result is good it is considered to be a good boiler, but if the result is poor, it is considered to be a poor boiler. Or, the reason for taking coal weights and water measurements may be to learn about the stoker machine. Again, it may be a question of a certain coal. But our practice has not been sufficiently accurate, or our methods comprehensive enough to give us a correct result, because of the different variable factors involved, but which, with our present methods, are treated as though they were constants.

For a good many years an effort has been made to simplify the matter, and to put it on such a basis that at least some of the complications would be eliminated. The paper that we have this evening is one of those efforts, and it is on a subject that is most worthy. I will say that any man who attempts to bring order out of this chaos is entitled to our gratitude.

I want to emphasize the first line of the abstract, "Furnace efficiency is the controlling factor in combined efficiency." What we call furnace efficiency is the most important factor involved. The quality of the fire may vary to such an extent that it will cause all the heat to be wasted, or make useful to the boiler as much as 90% of it. The steam-making process has necessarily about a 10% loss due to the fact that the gases must leave at a higher temperature than they enter the firebox. So we may have a range of from zero to 90% in heat delivery, due to the quality of the fire. But the advantage of a good boiler over a poor one is from 10 to 20%. The fault of the boiler may range to 20%. The fault of the fire may result in a loss of as much as 90%.

With reference to the ultimate analysis, I think it will soon become the practice to base the calculation for air supply for hydrogen on the available portion of the hydrogen, instead of on the total, because our assumption is that all of the oxygen in the coal is in combination with hydrogen. Therefore it is not necessary to supply air for this portion of the hydrogen. Thus, only the hydrogen not already satisfied requires an air supply to be provided for it. The result of this correct practice is to give a lower loss in the hot gases.

One of the features of the paper that pleases me very much is the suggestion that the values of the ultimate analysis be used as constants. That is a subject that I have studied for a long time. Some years ago I came to the conclusion that the composition of the coal—the coal proper—was a constant for any particular seam or locality in that seam. I now find it is a fact that the components of the composition are constant. We see the components as variables only when we deal with moist coal and dry coal; or, in other words, dry and moist fuel mixtures, having a variable content as to ash or moisture. But when we get to the substance itself, we will find it to be constant. For this reason it is absolutely unnecessary to make the numerous repetitions of ultimate analysis, or to get along without information that we should have, just because we cannot afford to pay for an ultimate analysis. Therefore, we may feel perfectly safe in employing the ultimate analysis, as well as the heating power, as a constant. As Mr. Harrington said, the variation is small, and this variation is due to the method of analysis, rather than to the composition of the coal.

The discussion which I have attempted to prepare is illustrated by a small collection of curves showing certain features which have a marked influence on the process of steam-making.

Figure 13 is a diagram which I made some twelve years ago, in an endeavor to determine what the drop in efficiency of a boiler amounted to, with a range in capacity. The curve marked "maximum results" was plotted by Mr. William Kent, from tests made by Mr. George H. Barrus. It presents a marked falling off, with

increase in capacity. "Kent's estimate" is a curve calculated by him to represent the probable drop, with an average condition. The curve marked "with 14% CO_2" was calculated by myself, to represent what would occur with good combustion. The curve

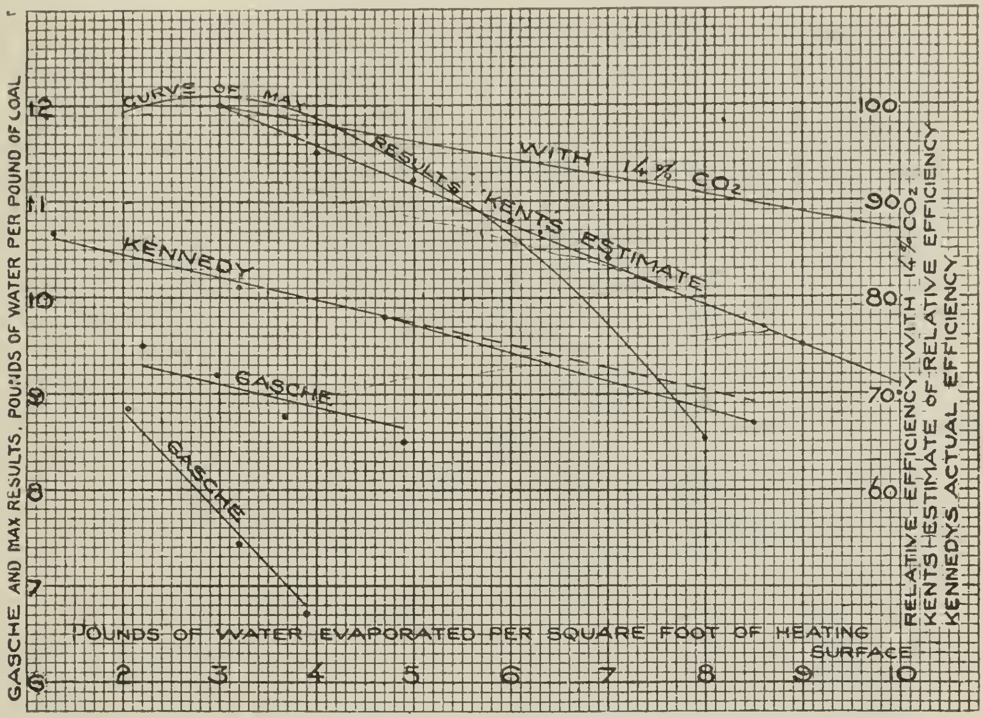


Fig. 13. Curves intended to show decrease of efficiency with increasing capacities, in steam generation.

marked "Kennedy" is from some very careful tests made by Professor Kennedy. In the third point there is a correction by dotted line, to overcome the influence of carbon monoxide in this test. One of the Gasche tests shows a marked falling off—much more than in the other. As his two tests were with the same boiler, it is apparent that combustion was quite different in the two instances.

The three curves,—with 14% CO_2, Kent's estimate, and Kennedy,—each based on a constant uniform condition of combustion, show a fair agreement, one with the other, and are of some service in showing the probable drop in efficiency of an average boiler. The curve based on 14% CO_2 is the one, however, which is in nearest agreement with that shown by Mr. Harrington.

Figure 14 contains a curve which is plotted on the same basis as those in Fig. 13; at 1,200 h.p. capacity it is equal to an evaporation of about 8.5 lb. of water per sq. ft. of heating surface per hour. In this we have a most striking contrast with the curves of Fig. 13, as the efficiency increases with the capacity. The reason for this is to be found, not in the boiler but in the condition of combustion. The curve was plotted from results of tests of coal, which

tests, however, are in no way different from a "test of a boiler" as we now conduct it. In each, the method consists simply in dividing the weight of the water by that of the coal. Thus it is not strange that we are confused. The reason why the curve of Fig. 14 rises

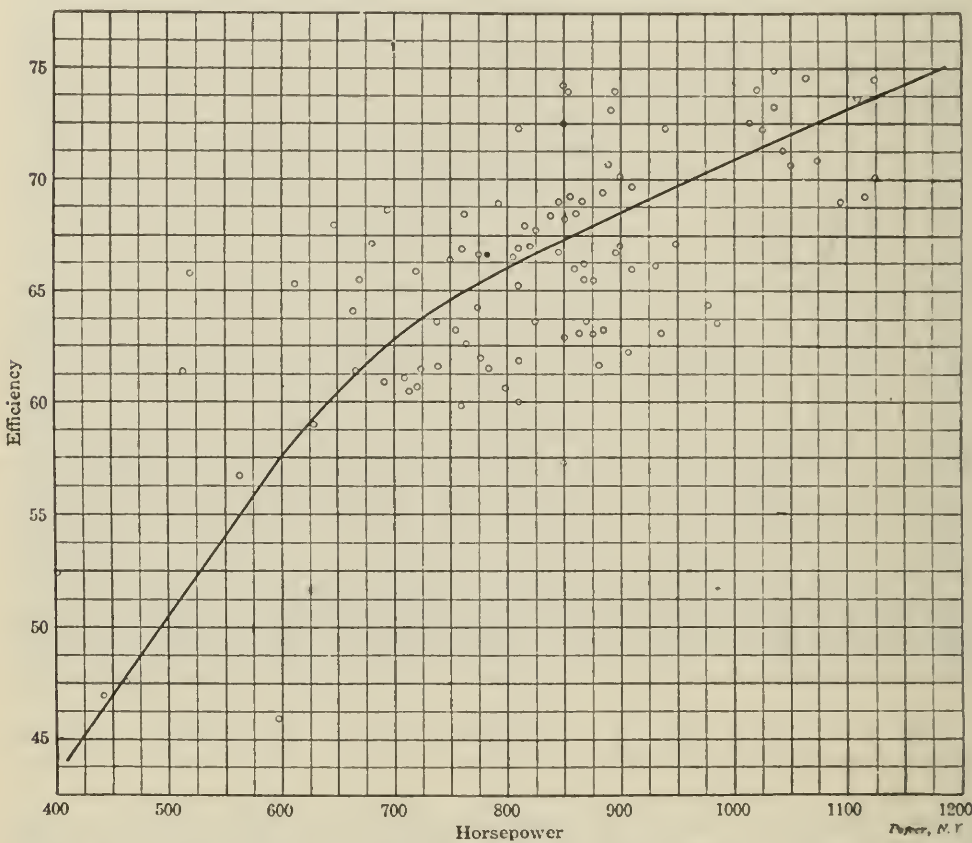


Fig. 14. Diagram showing the effect of good combustion in overcoming boiler loss, and in addition showing a large net gain in efficiency as capacity is increased.

with increase of capacity is that the best coal—best as to size, ash content, and quality—burned the easiest and most rapidly, for which reason a large quantity was burned with a good condition of combustion. Thus the cause of large capacity was the same as that which insured high efficiency. So the combustion feature was the controlling factor, not only entirely overcoming but absorbing the boiler loss, and in addition showing a large net gain. In dealing with curves such as those in Figures 13 and 14, it is necessary always to take into consideration the matter of combustion.

Figure 15 contains two curves based on results of some tests made a few years ago. The one marked boiler *A* represents loss with a poor boiler, and the other curve marked *B* represents a good boiler. Taking these two curves, with those of Fig. 13 marked "with 14% CO_2," "Kent's estimate" and "Kennedy," together with Mr. Harrington's curve, in Fig. 11, we have as good a collection

of data on the subject as I now know of, although at best it has only an approximate value.

Figure 16* is shown, as it has a bearing on the matter of efficiency. It concerns the performance of boilers *A* and *B,* of Fig.

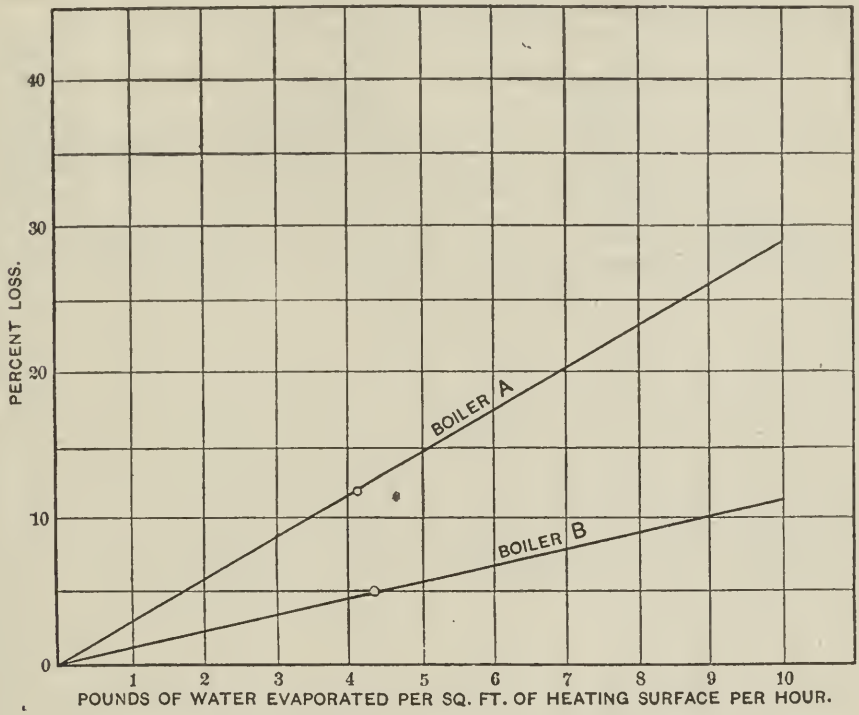


Fig. 15. Loss in hot gases with a good and a poor boiler at different capacities, zero of loss taken at steam temperature.

15, and another one. This diagram was prepared by Messrs. Ray and Kreisinger. The three boilers were identical, except for a difference in the length of the path of the hot gases through the heating surface. Each boiler contained 4,800 sq. ft. of heating surface. The gas travel of the single-pass boiler was about 13 ft., of the double-pass boiler 24 ft., and the triple-pass boiler 36 ft. The upper curves show efficiency in two tests. The lower curve shows final temperature of escaping gases. Curves of Fig. 13 assume that the efficiency of a boiler is constant for any stated capacity, but we see from this diagram and Fig. 15, that it is not so, as boilers may differ.

We are familiar with the work of Messrs. Ray and Kreisinger, and their exploitation of the theory of a constant efficiency of a boiler, irrespective of capacity. The upper set of curves, Fig. 17, shows the efficiency as dropping to a certain point, after which the curves become horizontal. These curves illustrate very well the Ray-Kreisinger theory, and it is considered that the portions where the

*Bulletin No. 18, U. S. Bureau of Mines, page 155.

efficiency is declining correspond to the capacities usually employed in stationary practice. It is to this flat part of the curve that Mr. Harrington has reference, in citing still larger capacities than those given in his Fig. 11. The matter is still further illustrated by Fig.

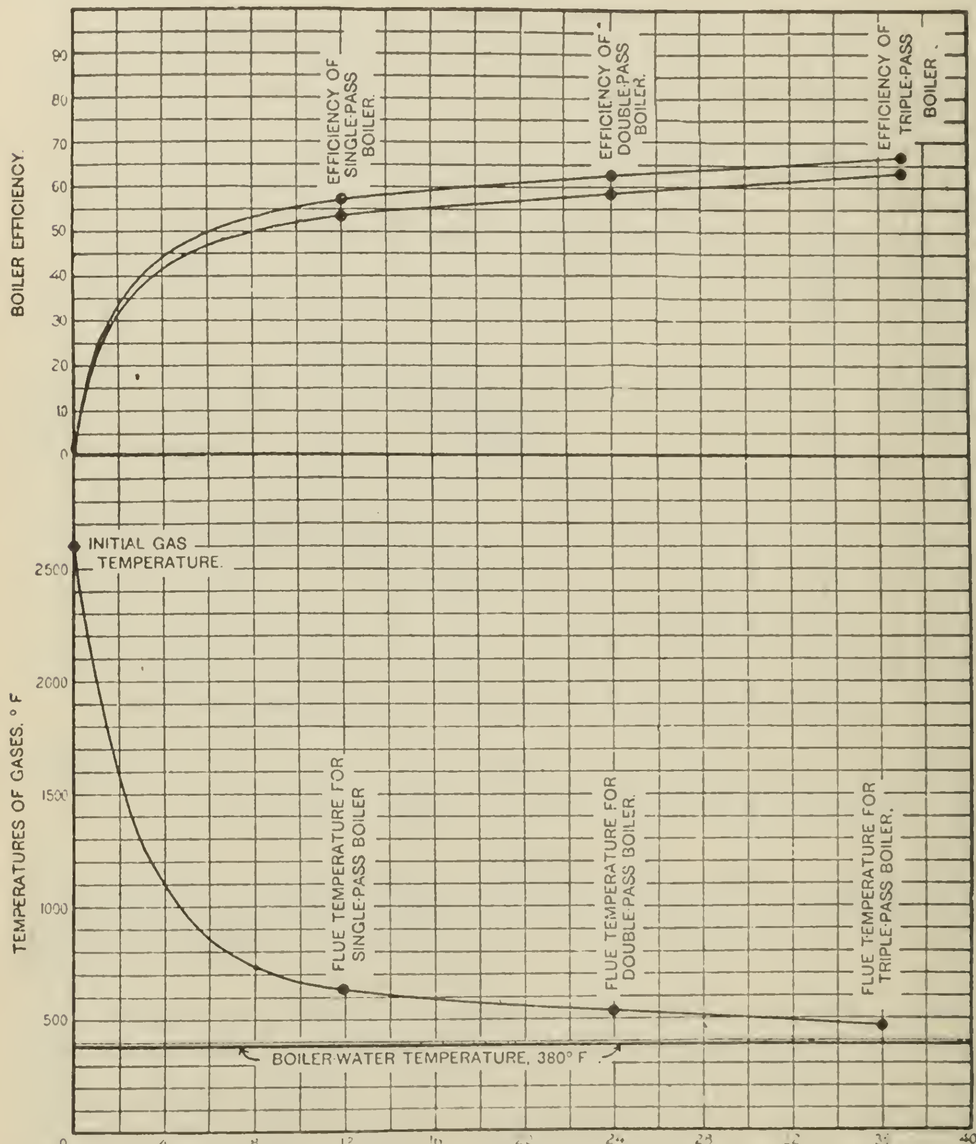
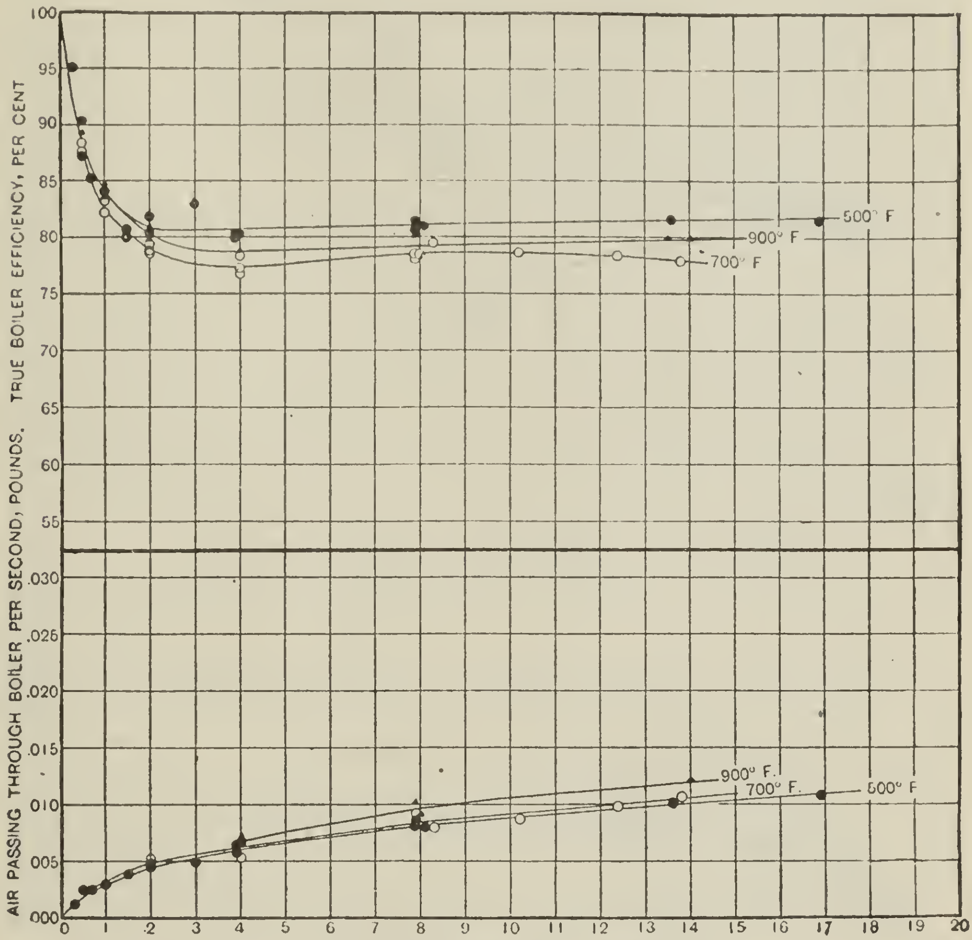


Fig. 16. Efficiency and temperature of gases at different points in path of hot gases, from boilers A and B of Fig. 15 and another one.

18, showing that after a certain point the temperature of the hot air leaving the boiler became constant, notwithstanding increasing capacity as exemplified by the curves in the upper part of the diagram.

Another factor tending, with our present methods of study, to complicate the matter of boiler performance is that portion of the

incomplete-combustion loss that, as yet, can only be measured as a difference in the heat balance, of which radiation is an unknown part. That this incomplete-combustion loss is a serious one, especially with bituminous coal, is shown by Figs. 19 and 20. Not-



Pressure drop of air while passing through boiler, inches of water.

Fig. 17. Diagram illustrating theory of constant boiler efficiency.

withstanding the evidence afforded by these two diagrams, which embody results of many tests made at the St. Louis World's Fair in 1904, it is still the common practice to charge most or all of the unaccounted-for loss to radiation. This has led to a belief that radiation is both a very large and rather a variable quantity. Now, however, there is sufficient evidence to show that radiation is much smaller than supposed; consequently, incomplete-combustion loss is greater than we have believed.

Recently the Detroit Edison Company erected some very large boilers, which have attracted much attention for that reason, and also because of elaborate tests made by Dr. Jacobus, of the Babcock & Wilcox Company, in which radiation and unaccounted-for

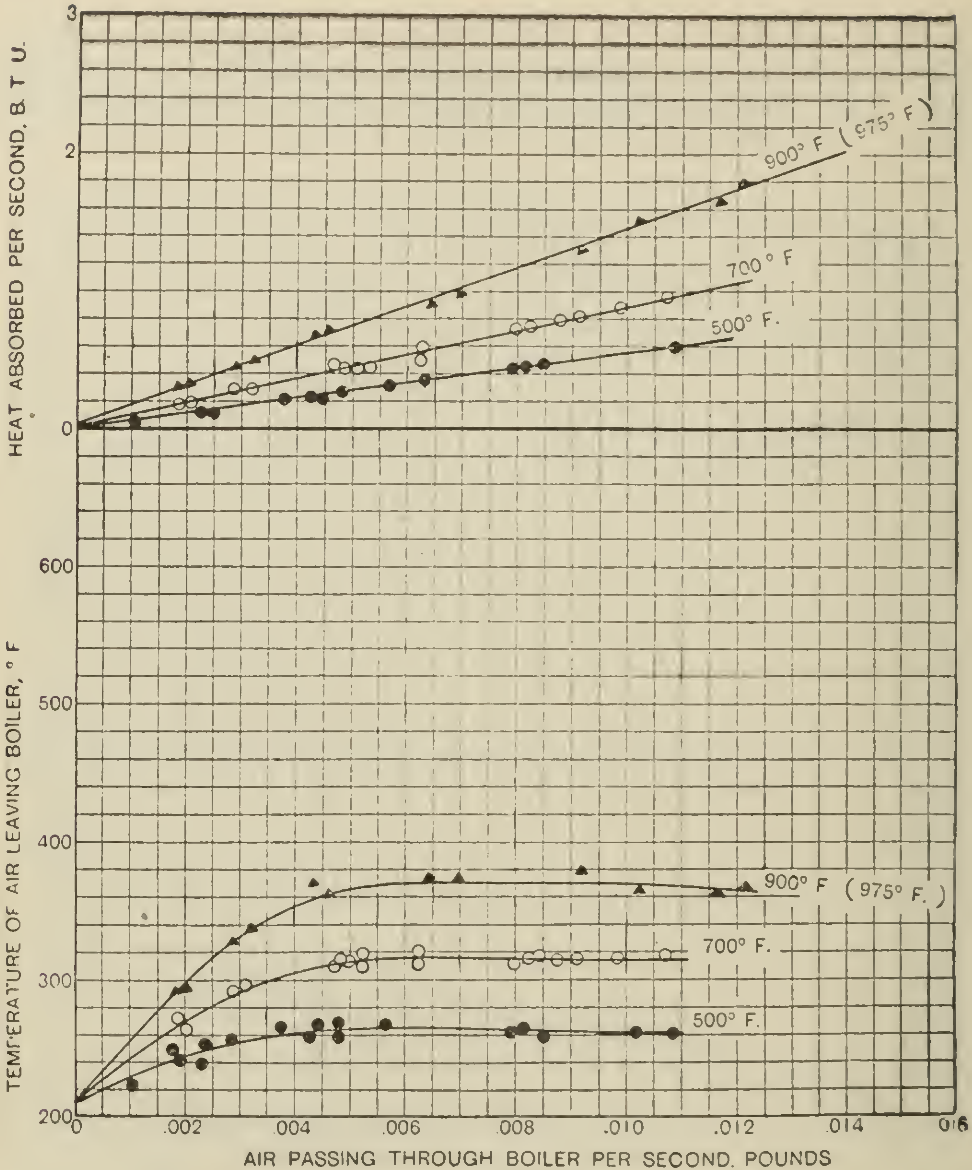


Fig. 18. Diagram illustrating theory of constant boiler efficiency.

loss amounted to only 2.76%, as given in a paper before the American Society of Mechanical Engineers. In his closure to the discussion he says that from very careful tests with oil fuel, the combined unaccounted-for and radiation loss was 2%; that this was verified by operating the boiler indefinitely, maintaining steam pressure, but making no steam, with 2% of the oil necessary to operate at rated capacity. That, I think, will in large measure help us to believe the statement made by Mr. R. S. Hole several years ago, that radiation amounts to 1% at rated capacity, on a basis of 10 sq. ft. of heating surface per horse power.

W. F. M. Goss, ASSOC. W. S. E.: Mr. Harrington has been successful in making plain certain facts with reference to steam-

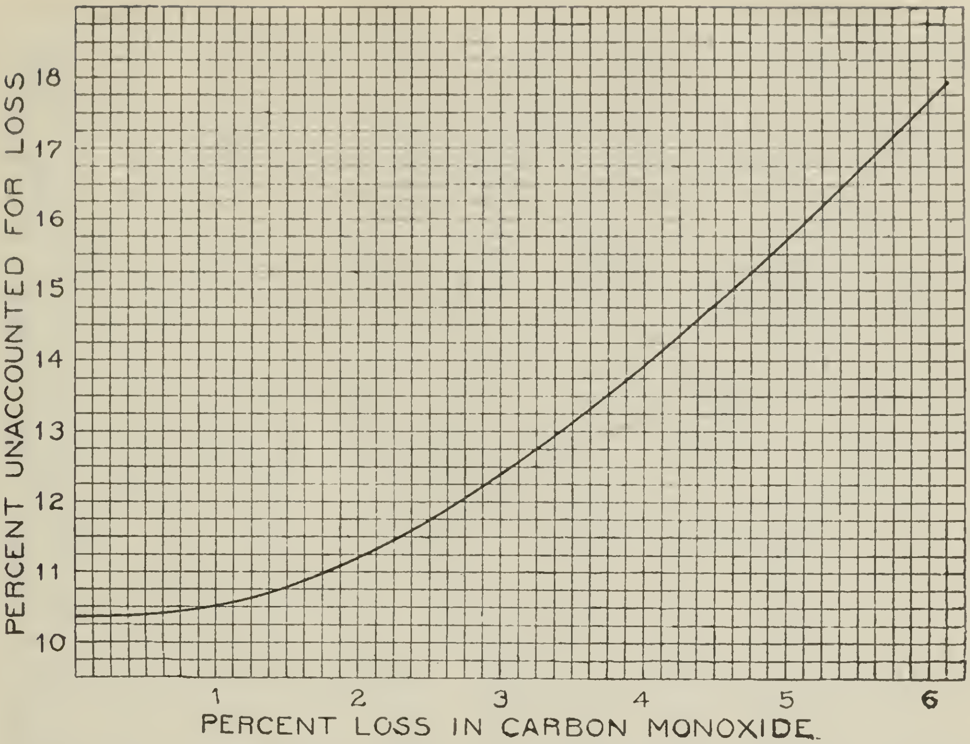


Fig. 19. Unaccounted-for incomplete-combustion losses, accompanying known carbon monoxide losses.

boiler performance which are fundamental. I want especially to commend the emphasis which he places upon furnace efficiency.

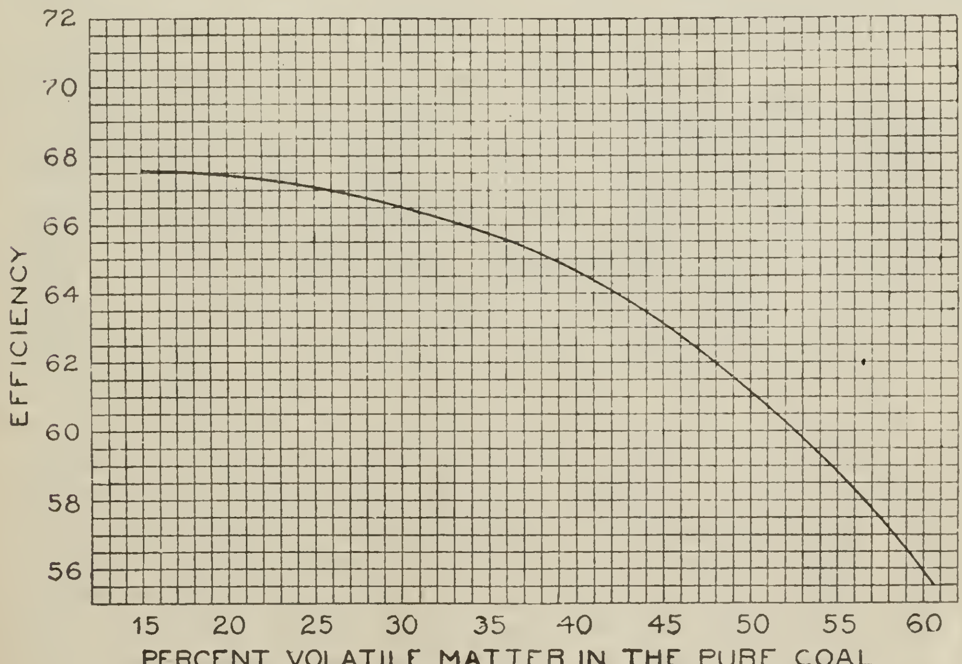


Fig. 20. Decline in efficiency due to volatile matter in coal, causing incomplete combustion losses.

Action at the grate and within the furnace constitutes the initial step in the process of converting the heat energy of fuel into steam, and any defect attending this initial step constitutes a limitation upon the success of each subsequent step. Maximum over-all efficiency is impossible without maximum furnace efficiency. Moreover, the problem of securing high efficiency in combustion is difficult, while that of conserving the heat made available by the furnace is comparatively simple. The problem is to get the heat of the fuel to the heating surface. This accomplished it will be found that the capacity of the metallic surfaces to absorb the heat developed is far greater than we have commonly supposed. Years ago, when cylindrical boilers were in vogue, from 16 to 20 feet of surface was necessary for the development of one horse-power. As the form of boilers has been changed and furnace construction has been improved, this allowance has been reduced step by step to 12, 10, 8, 6, and in locomotive service to 3 feet or less. Recent experiments have shown that if one considers the firebox of the locomotive alone, ½ of a square foot suffices for the development of a horse-power, and if one considers certain portions of the firebox, ¼ of a square foot is probably sufficient for the development of a horse-power; that is, a single foot of heating surface may transmit without injury as many as 2.000 thermal units per minute. These statements showing the capacity of the heating surface are suggestive of the ease with which the heat developed can be absorbed by a boiler, and they point at once to the furnace where the heat must be developed. This is a most promising subject for study and experimentation.

T. A. Peebles: The matter of heat balance, as presented tonight, opens up a question which has come to the attention of the stoker and boiler manufacturers. A guarantee is often asked for as to capacity and efficiency. In the case of a new installation, the boiler man and the stoker man get together, and satisfactory cooperation results in a test which will equal the guaranteed results. In the case of an old installation, the stoker man is required in some cases to give a capacity and efficiency guarantee. He has a dirty boiler, a leaky setting, and leaky baffles to contend with. In that case, the successful performance of the guarantee will sometimes require the stoker man to put one boiler setting in good condition. With the method of analyzing the heat losses and calculating the boiler efficiency on this basis, the stoker man has a basis for making a guarantee. He can guarantee to burn a certain number of pounds of coal, under certain draft conditions, per square foot of grate surface, with a given gas analysis and amount of combustible in the ash. The analysis of flue gas and the combustible in the ash are the only items of the steam generating process which the stoker man can control. After the gases reach the heating surface, he has no further control and should not be asked to go beyond the furnace in making a guarantee.

W. L. Abbott, M. W. S. E.: The underlying thought in the paper you have heard this evening is perhaps some pardonable reference to the improved Green stoker. But what attracted my attention more was the diagram on the next to the last page, showing the possibilities of a wide range of capacity with a nearly uniform efficiency. There was a time when the boiler maker selling a boiler would guarantee a certain evaporation and he would have to take his chance with the setting, with the furnace, with the coal, and with the fireman. Also the man selling the stoker would take his chances with everything connected with it. People did not appear to discriminate at that time and realize that each had a specific efficiency of its own, and no piece of the apparatus or of the process should be responsible for the rest of it. A piece of boiler iron, when fabricated into a boiler by one manufacturer, is probably just as efficient as when fabricated by another manufacturer, and the shape of the boiler has nothing to do with its efficiency, providing it gets an equal chance at the hot gases.

Let us consider, for a moment, the ultimate factors involved in the process of making steam. A furnace is a device in which to heat up air. A boiler is a device with which to cool air, and after that to use this heat to boil water. A furnace is a device to heat air, because, of the gases which reach the boiler, about nineteen-twentieths have to come through the grate, the other twentieth being the volatilization of the fuel which is on the grate. The purpose of the furnace is to provide a place in which the distilled gases may burn and in burning heat the air, just as the gas in the cylinder of a gas engine by its combustion merely heats up the air in the cylinder.

The capacity of a furnace to burn gas is limited, first, by its temperature, and, second, by its volume. The ability of a boiler to absorb heat is determined by the uniformity with which the gas may be distributed to all parts of the heating surface, by the extent of the heating surface, and by the velocity of the gas, and any effort to increase the capacity of the boiler and at the same time maintain its efficiency will be met by the limitations of the capacity of the furnace to burn the gas and by the capacity of the boiler to cool the gas.

The capability of a furnace to burn gases is a matter which scarcely receives proper consideration. Take the case of a boiler with what is known as a standard Babcock & Wilcox setting, in which the flame from the grate goes straight up among the tubes on the first pass; from the time the air enters the grate until the flame is cooled by contact with the first row of tubes is perhaps something like a fifth of a second. Now you will realize that combustion, to be complete in that length of time, must take place with almost the quickness of an explosion. It is physically impossible in that length of time to draw in the air, secure a proper mixture

with the evolving gas, and have it thoroughly burned. A great improvement was made when the design of furnaces was so changed that the gas, instead of going directly up among the tubes, was forced to travel a horizontal passageway, where it was enclosed in hot firebrick and was maintained at a high temperature, and where, instead of having but a fifth of a second in which to burn, the time was lengthened to perhaps a quarter or half a second.

Any increase of the amount of gas burned will necessarily shorten the length of time in which that combustion must take place. If it takes, say, a quarter of a second for the gas to go from the grate to the boiler tubes, running at 300 h.p., it will be about one-twentieth of a second if the working rate of the boiler be increased from 300 h.p. to 1,500 h.p. The result will be a lower efficiency through the loss of unconsumed gases escaping as carbon monoxide and hydrocarbons.

It therefore appears that the two principal factors which tend to materially reduce the efficiency of a boiler as its working rate is increased are, first, the loss of combustible in unconsumed gases, due to a reduction of time allowed for burning the flame, and second, a loss of heat in escaping gases, due to their increased volume and the decreased time which they are permitted to remain in contact with the boiler surface.

Mr. Bement: I believe that before very long we will come to an agreement on a factor for radiation loss. A well set boiler probably has very low radiation and another equally well set boiler has the same radiation. Thus, a well set boiler, as a general thing, would have a certain fixed radiation, and if we could agree on a constant for it, and use it in our heat balance, then we would add it to all our other determined losses and subtracting the sum from 100, the difference would be our true unaccounted-for quantity.

Prof. J. C. Peebles: I am particularly glad to see a sharp distinction drawn between the furnace efficiency and the combined efficiency of the furnace and the boiler. For a long time we have been in the habit of expressing the efficiency of the whole steam generating process in terms of evaporation. So many pounds of water evaporated per pound of coal, of course, makes a convenient and easy method of expressing efficiency. When we come to segregate the two ideas of efficiency, we have no convenient terms in which to express this furnace efficiency, if we want it by itself. Now, it seems to me that the proper method of expressing that efficiency has already been touched on; that it lies almost entirely in the flue gas analysis. If I say, then, to express the efficiency of the furnace, that the flue gas analysis is 12% CO_2, that will give a good idea of what that furnace is doing, assuming, of course, that there is only a small amount of combustible in the ash; if combustible runs above 50%, of course one is cutting efficiency down. But we well know that it is more economical to have, say, 20% or

25% combustible in the ash than to have holes in the fire or to have a foot of bare grate at the back, in the case of the chain grate stoker. So that the expression of furnace efficiency should be entirely in terms of the flue gas analysis, assuming, say, 12% CO_2 as the probable maximum towards which to work in using these middle western coals.

Another point that occurs to me, which has not been touched on to any extent, and which may be a little digression from the subject in hand, is this: If we can separate this furnace efficiency from the combined efficiency and can in some convenient way express that efficiency so that it is possible at a glance to know what it is, how can we make use of this information in improving our furnace performance? For instance, a man is running a boiler plant. He says, "I realize what furnace efficiency is, to an extent, at least. I know that it can be segregated from the combined efficiency of the whole generating unit, and that the flue gas analysis is perhaps as correct a statement of that efficiency as we have. Knowing all that, how can I go one step further and apply that to my boiler plant? How can I get a little more out of the coal that I burn?" It seems to me that that is the ultimate end toward which all this discussion of efficiency must tend. That is, we discuss efficiency for the purpose of improving efficiency, and while it may not be directly in touch with the line of discussion this evening, it seems to me it is an important point, nevertheless.

Assuming that the boiler man and the furnace man have done their duty, what can the operating man do to improve this efficiency? Mr. Harrington spoke of one thing which the operating man can do which he frequently overlooks, and that is to have a proper boiler setting. He ought to have a flue gas apparatus and should test the flue gas regularly; then he should look for leaks in the setting. Mr. Harrington spoke of a case in which 40% of the total gas that went up the chimney leaked through the setting and never went through the fire at all. That is probably an extreme figure, but I doubt not a good many cases could be found that are just about as bad. In what experience I have had in boiler tests and with gas tests I have frequently found that a little investigation around a setting, particularly around the fire door or around the inspection door where the brickwork is put up around the door, will reveal leaks; a torch will be sucked into the cracks, indicating a large leakage of air. If those leaks are stopped, I think the efficiency will be improved considerably.

Many times an operating man thinks that a little combustible in the ash means a big waste. It may not mean nearly as much waste as holes in the fire. If one can carry uniform fire and see that the grate is covered at the back, even though some coal goes over into the pit, the efficiency will be improved. Watch the setting, keep it tight, see that there are no leaks where air can get

in, and keep the grate covered. With middle western coals it is not always possible to carry as thick a fire as desired, and the thinner the fire the more chance for holes to burn through or the grate to be bare at the back; but carrying the fire as thick as possible, keeping the fire uniform and clear to the back, will prevent the infiltration of excess air and improve the efficiency.

That much I think the operating man can do, assuming that the boiler man and the furnace man have done their duty in the matter of design.

Osborn Monnett: Mr. Harrington's paper serves to emphasize to us how widely separated the boiler as a heat-absorbing mechanism is from the furnace as a heat-generating device. If we were in the market today for a boiler, we could go out and get from a dozen different boiler salesmen practically equal boiler efficiency guarantees, regardless of the shape or design of the boiler, so that, speaking of boiler efficiency alone, they would all guarantee about the same commercial efficiency. The limiting factor in the selection of the boiler, therefore, would not be any wonderful increase of boiler efficiency over some other boiler which we might select, but it would be facilities for cleaning, facilities for internal inspection or economy of floor space or head room, or some other feature which had a bearing upon the plant in which we intended to install the boiler.

On the other hand, Mr. Harrington shows that the controlling factor in the combined unit is the furnace, and it requires a separate study. If we could design our mechanical stoker installations so that the commercial efficiency on varying loads was within a reasonable range so as to obviate the necessity of banking fires, we would make a wonderful advance in the over-all economy of power-plant operation. I am very glad to see Mr. Harrington take up the matter in so vigorous a manner and bring it to our attention in this way.

In regard to the heat balance which he shows on the Green Engineering Company's sheet, it might be, as he suggests, of value to add one more column to this balance and express in percentages the various items listed. It might be that we would have a heat balance of, for instance, Pocahontas coal, where the B. t. u. values would all be high, the next item on the heat balance would be high, and the other items would vary according to the characteristic of the coal. But the next heat balance that we had to study might be of a lignite, where the B. t. u. available would be much less, and in order to compare the two easily it might be of value to express the different items in percentages of the whole, so that they could be more readily studied.

I would ask Mr. Harrington how he gets the heat loss due to cinders and how he classifies these cinders.

Mr. Harrington: The only way in which the heat loss due to

the cinders can be determined is by an actual measurement of the cinders and a B. t. u. determination. An underfeed type of stoker has run in the neighborhood of 3% of the coal fired. With the chain grate, where the draft is not localized, and where the velocity of the entering air is less, it will run so low, in many cases, as to be inappreciable and negligible. We have it in here as it is a possible loss, and is charged against the furnace, because if the stoker or the stoking device were 100% perfect it would not reject anything unconsumed. As a matter of fact, we usually neglect that item unless we know, due to some peculiar condition, that there is actual loss.

Lewis M. Ellison: One thing impresses me very strongly in this consideration, and that is the great increase in capacity with only a slight decrease in efficiency. The probability of such performance will depend, in my opinion, largely upon the type of the boiler. A water-tube boiler, based on 10 sq. ft. of water heating surface per horse-power, having a rapid circulation, will develop a surprisingly high percentage of overload, with only a slight falling off in efficiency.

I do not believe that we have given the consideration to the importance of rapid circulation that the subject deserves. As before stated, a water-tube boiler having a rapid circulation and based on 10 sq. ft. of water heating surface will give nearly as high an efficiency at about three times the normal rating. I believe that before many years we will have a boiler of forced circulation, that will give as high an efficiency with about 3 sq. ft. as the average present water-tube boiler is now giving with 10 sq. ft. This may account, to some extent, for Mr. Harrington's having obtained about as high an efficiency in developing 1,500 h.p. as in developing 300, but the boiler must have had an unusually rapid circulation.

Alfred J. Saxe, M. W. S. E.: I agree with Mr. Ellison on circulation and tight boiler-settings. Last year I was asked to suggest some improvements in a power plant near Chicago. There were two 300 h.p. boilers in the plant and the operators were forced to run both of them to accomplish the required results. This did not allow time for properly cleaning and washing the boilers, which had to be done on Sunday at overtime pay, and it was always a hurry-up job. I installed stokers under the boilers, covered the settings with ½ in. of asbestos cement, and gave them a coat of canvas and two coats of paint. The boiler settings formerly were rather leaky, but they were no worse than thousands of other boiler settings which are operated every day in Chicago.

After doing this work the plant was operated with one boiler instead of two, and resulted in a saving in the fuel bill of from 40% to 45%, nearly cutting it in two. But we encountered trouble. The plant was carrying about 550 or 600 h.p. on a 300 h.p. boiler during most of a day of ten hours and the water was very bad.

The bottom tubes began to show signs of giving out, blisters forming on them. I told the engineer in charge that he must be letting them scale up, but he claimed that they were perfectly clean. The following Sunday I inspected them and found, as he had said, that the flues were clean, but that they still blistered. The circulation of water in the bottom tubes was not rapid enough to carry off the intense heat, while in the top tubes, where the temperature was lower, it was too rapid. We came to the conclusion that the heat was absorbed so rapidly in the front, bottom tube that the water was made into steam before it got out of the tube, and that that part of the tube was practically dry while it had water at the other end. We then placed some obstructions in the first five rows of upper tubes, laying in old 1-in. bolts. The resistance of the bolts retarded the circulation in the top tubes and I think increased it in the bottom tubes. No further trouble has been experienced with the bottom tubes. They are in fine condition and the boiler develops from 550 to 600 h.p.

Since making these experiments I have read an article in a little pamphlet sent out by the Pemberthy Injector Co., which describes similar troubles and tribulations of an engineer, who overcame them in practically the same way, except that he used cast-iron bushings in the upper row of tubes. The bushings are probably an improvement over the bolts, although the latter are easily removed for cleaning purposes.

I think that the first five or six rows of tubes over the fire of a B. & W. boiler, vertically baffled, evaporate as much water as the rest of the boiler, which is equal to 25 lb. to 30 lb. per sq. ft. of heating surface per hour. The upper half of the last pass of this style of boiler does very little work, as the temperature of the gases in it is very low. This is quite noticeable when cleaning, as there is much less scale in this part of the boiler.

In regard to covering the brickwork of boilers with some non-conductor of heat to make them air-tight, this has been a hobby with me for some time, and I can usually make a saving thereby of from 10% to 25% in the fuel bill. It is not necessary to have the covering very thick, if it is air-tight, so that no air comes into the setting except through the proper openings of the furnace. In fact, no air should ever enter a boiler setting back of the bridge wall. In the case of the boiler plant just mentioned, the CO_2 content in the uptake was raised from 4½% before covering to 10% afterwards.

Closure.

Mr. Harrington: Answering Mr. Saxe, the question of tube trouble is a subject in itself, and I will simply say that I have forced a 600 h.p. boiler up to 2,000 h.p. for a few minutes and up to over 1,800 h.p. for an hour and a half or two hours, without the slightest indication of any trouble. It is evidence that we know very little about tube trouble.

I was glad to have Professor Peebles talk as he did. He asked how we could apply practically this problem of furnace efficiency. The understanding and knowledge of what furnace efficiency is, is distinct and clear. I think we know what contributes to furnace efficiency. The trouble is to get the operators to understand the entire situation. A combustion education for the operating people is really what is required. They will throw in coke by the ton, day after day, and see much of it going out unburned, with the ashes, and will not know what to do to stop this waste. In order to lessen it they will run a fire on a chain grate two or three feet short, and because they are getting a fine looking ash they think they are getting more fuel efficiency. That is plain, every day, ignorance. Whole plants are operated in that way, and unfortunately, from my standpoint, the chain grate or the stoker is usually charged with all the inefficiencies of both the equipment and the operation. I might say that the only trouble jobs we have are trouble jobs with the operatives, with the methods, or, in certain cases, with the draft apparatus. If the plant owner and the boiler room foreman or whoever is in charge of the plant, will be careful to find out what constitutes furnace efficiency or over-all efficiency, supply himself with draft gauges, with a CO_2 apparatus, make an occasional analysis of the ash, just to keep in touch with that department, use horse sense about plugging up cracks in his boiler settings, keep his dampers open and closed at the proper times, keep the fire even, and watch the gas, he can, with a reasonable amount of care, keep the plant efficiency up to a fair degree. There is nothing impossible about it, and usually nothing difficult.

As I interpreted Mr. Abbott's remarks, he takes direct issue with the proposition that a horizontal efficiency curve is possible. I do not know whether I am correct in that, but that was my understanding of his remarks, for two reasons. In the first place, he assumes that increasing the rating of the boiler or rate of combustion, and increasing the volume of the gases delivered to the boiler, is the equivalent of cutting off the heating surface of the boiler. I do not believe that is correct reasoning, because I know, and it has been demonstrated in a great number of cases, that a boiler of, say, 6,000 sq. ft. of heating surface will run at that rating with a flue temperature of 425 deg.; and one can nearly double that rating and the flue temperature will not go up to more than 550 deg. I have run this same boiler up to 1,300 h.p. or 1,400 h.p. and the flue temperature would not be over 550 or 600 deg.

The curve that I show in Fig. 1 gives a rating of nearly 1,200 h.p. with a temperature of 615 or 620 deg. When that same boiler was forced up to 1,800 h.p., the flue temperature was only a little over 700 deg. I contend that it is quite within the bounds of possibility and almost within the bounds of good practice to double-rate, developing a horse power on 5 sq. ft. of heating surface and in

many instances, in case of a peak and where capacity is the one prime requisite, one can triple-rate that boiler if he has the heat to put into it, and he will save money by so doing. The boiler will take up that heat. It will drop off in true boiler efficiency 3% or 4%, but the over-all boiler room efficiency will actually be improved, owing to not having to put other boilers in service, the loss from which is far greater than the 3% or 4% loss by heavily over-rating the units in service for a short period.

I do not believe there is any comparison between the two methods of running a plant. As far as furnace efficiency is concerned, falling off with increased rate of combustion, there is a limit to furnace capacity. A furnace can be overrated just the same as anything else can be overrated, but the furnace which I have in mind and which I have been talking about is a furnace of a capacity of 1,200 h.p., and when it is running at 600 h.p. it is running at half its capacity. If the full capacity of the furnace is 1,800 h.p., why should it not be run up to 1,800 h.p.?

Furnace capacity is primarily the power to retain gases in the furnace only until the combustion is complete or practically so. That is the question of a sufficient supply of air and sufficient intermingling of the gases with the air, and, of course, surrounding brickwork of such a nature that it will stand the temperatures evolved. But it is perfectly possible, with a furnace of commercial size (12 ft. 7 in. wide, with a Babcock boiler, 21 tubes wide, having the boiler set 9 ft. high with a combined arch effect, say, 7 ft.), to get 1,800 h.p. out of that furnace with Pocahontas coal, and it will not smoke and it will not lose in efficiency. Of course, with high volatile western coal, that furnace would be inadequate for this rating. But with high volatile western coal, the furnace should be sufficiently large to take care of the increased volatile combustible which those coals contain. It is a question of size and not of combustibility. It can be done if you know how to proportion your furnace and are willing to give the space to it. If power plant operatives, owners, and managers would appreciate the saving to be effected by a properly-designed furnace, they would take all the real estate that is required, even though it is right in the heart of Chicago. It would pay for itself before that station is half worn out.

When a furnace of adequate size is forced under the proper conditions, the efficiency remains practically constant, and the draft in the furnace is increased. When the draft is increased, the thickness of the fuel bed is presumably increased so as not to pull in an excessive amount of air. If the CO_2 is kept constant at all ratings, the efficiency is bound to be exactly the same. If you burn up your coal and if you do not use more air than you need, your furnace efficiency is absolutely the same, because the loss in the ash pit and excess of air in the gases are the only things that the furnace is charged with, and that is why I contend that the efficiency

of the furnace is absolutely independent of the rate of combustion. There is not a thing in the oxidation process that has any connection whatsoever with the rate of that process. There is no reason why one cannot oxidize a pound of carbon in a minute with just the same efficiency that he can in an hour. As a matter of fact, the higher the rate of combustion the higher the temperature, and reacting on the power to transmit heat through a tube, probably the higher boiler efficiency will result. In a curve of capacities and CO_2 analyses, it will be noted that the CO_2 analysis follows the curve of capacities. The higher the draft at one's command, the thicker the fuel bed he can carry, and consequently the more complete the oxygen absorption. The more complete the oxygen absorption, the greater the efficiency of the combustion process. Consequently the furnace efficiency in practice should improve with the rate of combustion.

That, as I understand Mr. Abbott's remarks, is the exact opposite of what he said.

The whole thing is based, however, on the assumption that the furnace is of sufficient size to hold the gases until the combustion is complete. It is unreasonable to expect a vertically baffled Babcock boiler set 6 ft. high to have the same furnace capacity as one set 13 ft. high, as they are being set in Chicago today. That is one of the necessary considerations that has to be provided for in advance.

As a matter of fact, the efficiency of the furnace improving with the rate of combustion partially offsets the decrease in boiler efficiency with increased rate of combustion, so that there is secured a combined efficiency curve which will be nearly horizontal.

IN MEMORIAM.

CHARLES WESLEY BROWN, M. W. S. E.

Died May 25, 1912.

Charles Wesley Brown was born in Jacksonville, Morgan County, Illinois, November 29, 1867, the son of James Wesley and Catherine Thompson Brown.

His early education was obtained at the Jacksonville High School, from which he graduated in 1887. After engaging in occupations along engineering lines, he studied in the Illinois College at Jacksonville, Illinois, in 1890-1891. He afterwards attended Purdue University, LaFayette, Indiana, graduating with the degree of Bachelor of Mechanical Engineering and Electrical Engineering, with the Class of 1894. Mr. Brown earned his way through college.

Soon after graduation he returned to Jacksonville and entered the employ of the City Engineer. He became City Engineer of Jacksonville in 1895, which position he filled to the end of 1904. He then opened an office as Consulting Engineer. The engineering work for the State Institute for the Blind and Insane was under his direction, and he was Consulting Engineer for J. Capps Sons.

Limited, 1897-1907. His principal practice was municipal and drainage engineering.

He was a close student in horticulture and agriculture and took a great interest in the reclamation of swamp and overflow lands. He was Consulting Engineer for the cities of Beardstown, White Hall, Carrollton, Petersburg, Centralia, Anna, Jacksonville, Lewistown, and other Illinois cities; designing, constructing and maintaining waterworks, sewer systems, grades, bridges, pavements and lighting systems. He was Consulting Engineer for the White Hall Railroad Company, Prairie State Traction Company, and Beardstown & Quincy Railroad Company. He was Chief Engineer of the Coal Creek Drainage and Levee District, the Crane Creek Drainage and Levee District, and the Big Lake Drainage and Levee District of Schuyler County, Illinois; the Meredosia Drainage and Levee District and Indian Creek Drainage District of Cass County, Illinois; the Scott County Drainage and Levee District and the Big Swan Drainage and Levee District of Scott County, Illinois; the Hartwell Drainage and Levee District of Green County, Illinois; the Coon Run Drainage and Levee District, the Sny Drainage District above Hannibal, Missouri, the Last Creek Drainage District, and the Town Brook Drainage District. He was Consulting Engineer for a limited period for the Sny Island Drainage and Levee District of Pike County, Illinois; designing, constructing, operating and maintaining their works of levees, ditches, tiling, road and bridge work, and pumping plants and in the organization of the Districts, and the spreading of assessments for damages and benefits. He was high authority in drainage matters, and as Chairman of the Committee on Legislation of the Association of Drainage and Levee Districts of Illinois, of which he was a Charter Member, was instrumental in having passed many progressive, necessary, and valuable amendments to the Drainage Act of Illinois for agricultural, mining, and sanitary purposes. He had a large practice in farm-land drainage by tiling, and took great pride in making useful, waste areas in the corn belt, substituting tiling for open ditches.

In the winter of 1911, the City of Jacksonville, Illinois, voted to pass under the commission form of government, and in April of the same year, Mr. Brown was elected one of four commissioners. As his part of the duties he had charge of public property, lighting, and water, and all engineering features of the city. He did not seek this office; it was forced on him by the best citizens of Jacksonville.

On May 25, 1912, while at work in his office in the discharge of his duties, he was shot and killed by a former police officer of the city, the assassin afterwards committing suicide. The act was that of a man temporarily insane.

Mr. Brown was a man of sterling integrity. He had a kind

word for everyone; hatred and revenge had no place in his character. He was an indefatigable worker and accomplished a prodigious amount of labor. His time was always fully occupied, and only his marked ability enabled him to meet his many pressing engagements and undertakings.

On June 10, 1897, Mr. Brown was married to Miss Lotta Esta Thompson of LaFayette, Indiana, who died in November, 1901, leaving one child, Laura Esta Brown, who survives him. On September 3, 1903, Mr. Brown was united in marriage to Miss Nellie Hill of Jacksonville, who survives the husband and cares for his child. He was a member of Trinity Episcopal Church. Mr. Brown became an Active Member of this Society February 4, 1910.

(Signed) Jesse Lowe,
W. F. M. Goss,
Committee.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, October 21, 1912.

An extra meeting of the Society (No. 796), the Hydraulic, Sanitary, and Municipal Section, was held Monday evening, October 21, 1912. The meeting was called to order at 8:30 p. m., with Mr. Langdon Pearse, Vice-chairman of the Section, presiding, and about 35 members and guests in attendance.

The Chairman introduced Mr. George W. Fuller, of New York, who addressed the meeting on "The Permissible Limits of Sewage Dilution." Discussion of the subject followed from Prof. E. O. Jordan, University of Chicago, and Messrs. W. S. Shields, C. D. Hill, Langdon Pearse, and G. W. Fuller.

Mr. B. J. Ashley offered by resolution a vote of thanks to Mr. Fuller for his interesting and valuable address.

Meeting adjourned at 9:50 p. m.

Extra Meeting, October 28, 1912.

An extra meeting of the Society (No. 797), being a joint meeting of the Electrical Section W. S. E. and the Chicago Section A. I. E. E., was held Monday evening, October 28th, convening in Fullerton Hall, Art Institute, about 8 p. m.

The meeting was called to order by Mr. R. H. Rice, Chairman of the Chicago Section A. I. E. E., who announced the subjects for the meetings to be held in November and December, and then introduced Mr. W. C. Armstrong, President of the Western Society of Engineers, as Chairman. Mr. Armstrong, after a few words of welcome, presented Dr. Charles P. Steinmetz, who addressed the meeting on "Some Problems in Electrical Engineering." Some questions were asked of Dr. Steinmetz by Messrs. W. E. Williams, Stafford Montgomery, and others, which were replied to. There were about 400 in attendance. The meeting adjourned about 9:30 p. m.

Regular Meeting, November 4, 1912.

A regular meeting of the Society (No. 798), was held Monday evening, November 4th. The meeting was called to order at 8:20 p. m., Mr. A. Bement, Vice-President, presiding, and with about 40 members and guests in attendance.

The minutes of the preceding regular meeting, held October 7th, were read and approved.

The Secretary reported from the Board of Direction that applications for membership had been received from the following:

Robert R. Caldwell, Beloit, Wis.
Fred J. Postel, Chicago.
Charles S. Holcomb, Chicago, transfer.
Bernard Duchscher, Chicago.
Osborn Monnett, Chicago.
Clarence A. Money, Chicago.
Edward E. Reddersen, Champaign, Ill.
Charles L. Samson, Harvey, Ill.
Charles M. Kob, Chicago.
L. B. Sairs, Chicago.

Also that the following had been elected into membership:

Henry M. Goodman, Honolulu, T. H.	Associate Member
Walter S. Cadwell, Chicago	Member
Julius R. Hall, Chicago	Member
Walter S. Lacher, Chicago	Associate Member
Robert D. Townsend, Chicago	Member
Frank S. Musser, Chicago	Associate Member
A. H. Cameron, Minneapolis, transferred from Junior to	Associate Member
V. H. Aiken, Fargo, N. D.	Junior Member
J. H. Spengler, Chicago	Associate Member
E. G. Blackmer, Chicago	Affiliated Member
E. H. Ashdown, Chicago Heights, Ill.	Junior Member
Samuel Dauchy, Chicago	Member

The Chairman then introduced Mr. Osborn Monnett, Chief Smoke Inspector for the city of Chicago, who presented his paper on "New Methods of Approaching the Smoke Problem." At the conclusion of the paper some lantern slide views were shown, illustrating the improvements in the smoke conditions of this city. The Secretary read a letter from Prof. L. P. Breckenridge, of the Sheffield Scientific School, New Haven, Conn., commenting on the paper. Discussion followed from Messrs. A. Bement, Paul P. Bird, A. L. Rice, C. W. Corning (C. & N. W. Ry. Smoke Inspector), W. A. Pittsford (Smoke Inspector), W. L Jackson (Operating Engineer, First National Bank Building), H. Misostow (Smoke Inspector), Chas. W. Naylor, and R. B. Drake, with a closure from the author.

Meeting adjourned at 10:25 p. m.

Extra Meeting, November 11, 1912.

An extra meeting of the Society (No. 799), the Bridge and Structural Section, was held Monday evening, November 11th. The meeting was called to order by Mr. F. E. Davidson, Chairman, at 8:30 p. m., with about 20 members and guests present.

The Chairman introduced Mr. E. S. Pennebaker, Jun. W. S. E., who read his paper on "An Economical Design for a Timber Cotton Shed." Some discussion followed from the Chairman and Messrs. H. S. Baker, J. F. Brown, Ernest McCullough, N. M. Stineman, and the Secretary, with explanations and replies from the author.

Meeting adjourned at 9:30 p. m.

Extra Meeting, November 18, 1912.

An extra meeting of the Society (No. 800) was held Monday evening, November 18th. The meeting was called to order about 8:20 p. m. by President Armstrong, with about 25 members and guests in attendance. The President introduced Mr. Edmund T. Perkins, M. W. S. E., who read his paper, "The National Aspect of the Reclamation of Swamp and Overflowed Lands." After the reading of the paper, a number of lantern slide views were shown, illustrative of the subject. Discussion followed from the President and Messrs. L. E. Cooley, A. Bement, S. T. Smetters, Wm. Artingstall, J. H. Warder, J. Gibson, with explanations, replies, and closure from Mr. Perkins.

Meeting adjourned at 9:30 p. m.

J. H. Warder, *Secretary.*

BOOK REVIEWS.

The Books Reviewed Are in the Library of This Society.

The Design of Mine Structures. By Milo S. Ketchum, C. E., Dean of College of Engineering, University of Colo. McGraw-Hill Book Co., New York, 1912. 1st ed. Cloth; 6 by 8½ in.; pp. 459, including index; numerous illustrations. Price $4.00 net.

The author's preface states that "the book is written for the young engineer or student who has had a thorough course in applied mechanics and statics, and for the structural engineer who wishes to become familiar with this much-neglected field." As such, the book is a valuable addition to the designer's library, as well as supplemental text for the student. The author's purpose is to limit himself to a discussion of the structural features of mine buildings. Incidental to this, however, much valuable information is given concerning hoisting, screening, and the various operations which are a part of ore or coal handling at the mine.

These various processes are chiefly outlined in descriptions of the many plants that are used to illustrate the work. A short review of the contents will be of interest. Three main parts are made of the general subject.

Part I treats of the design of head works for mines, and these are discussed under head frames, rock houses for iron mines, and coal tipples. These are defined and classified in Chapter I. Preliminary to the actual mathematical part of designing, a discussion is given of hoisting systems, ropes, cages, skips, cars, landers, safety devices, etc. The design of head frames is taken up theoretically, first in simple frames, and then in statically indeterminate structures. Designs are also followed out in detail, and numerous examples are illustrated and described. The last part of Chapter I is devoted to coal tipples.

The author's classification of types is broad enough to cover most of the structures that have been built. The operations of dumping, screening, weighing, etc., in the various types of equipment for these purposes, are perhaps completely enough described for the purpose of the text. Following this, brief directions are given for the designing of coal tipples. The many installations used for illustration are representative of the various types and for the different fields in the coal mining states. For the design of coal tipple towers, the reader is referred to ore head frames which are so well treated in the preceding chapters.

It is to be regretted that more information is not given concerning the parts of coal tipple designs which are difficult to analyze, such as stresses from self dumping cages, stresses in guides and supports, and stresses produced by shaking screens.

In Part II, which treats of The Design of Mine Buildings, the same excellent methods and matter are found as are contained in the author's "Mill Buildings" and "Walls, Bins, and Grain Elevators." This part is in substance these two books condensed; the parts pertaining particularly to Mine Buildings being emphasized. Examples are given which illustrate the subject fully. The beginning chapter consists of the analysis of various types of trusses, trestle and building bents, and the following chapter takes up the design of steel buildings. In the first chapter the analysis and design of bins and retaining walls are covered and fully exemplified.

The chapter on the design of coal washeries consists of a short explanation of various types of jigs, and sizing and draining screens, followed by a description of two different types of washeries: one of timber and one of steel.

A chapter on coal breakers again briefly outlines methods of handling coal in this type of plant, then illustrates three breakers of different types. The last one, a mammoth structure of reinforced concrete, suggests the appropriateness of this form of construction for buildings about the mine.

The chapter on miscellaneous structures discusses the following:

A steel re-screening plant for coal.

A fluorspar mining and milling plant.

A timber railway trestle, and a large reinforced concrete retaining wall.

Part III "includes a discussion of the details of designs of mine structures, with tables, drawings, and data to be used in design, also a discussion of costs of mine structures in detail." Data on shop details, corrugated steel, and many tables not found in rolling mill handbooks, are supplemented by tables of costs and detail estimates for steel buildings.

Three appendices contain instruction for designing and specifications for structures in steel, timber, and reinforced concrete.

The greatest development in plants for handling coal at the mine has taken place in the last ten years. Improvements in handling the product and in the design of the structures themselves are now taking place so rapidly that the author has found it impossible to do more than indicate types. Mine buildings can never be as nearly standardized as mill buildings, but the work at hand has done much to indicate the best types. It will be as great, if not a greater, help to the designer in this class of work than the author's previous works on other structures have been to the designer of industrial plants. R. G. L.

Treatise on General and Industrial Inorganic Chemistry. By Ettore Molinari, Ph. D., Professor of Industrial Chemistry in Commercial University, Luigi Bocconi at Milan. Third revised and amplified Italian edition. Translated by Ernest Feilmann, B. Sc., Ph. D., F. I. C. Blakiston's Son & Co., Philadelphia. 1912. Cloth; 6¼ by 10 in.; pp. 704, including index; 280 illustrations; one colored plate. Price, $6.00 net.

The contents of this book is divided into three general parts, followed by a short appendix, and these are subdivided into many groups and subgroups. The principal divisions take into consideration purely theoretical chemistry, non-metallic, and metallic elements. In this first part, 125 pages, the fundamental laws of chemistry and physical-chemistry are briefly gone into with their relative bearing upon technical application. Intermingled with these laws is given a brief history of early chemistry, both from an industrial and theoretical standpoint, which makes very interesting reading.

In the second part, 382 pages, the author deals with the chemical industries pertaining to the non-metallic elements. These are taken up in periodic succession as far as possible, and each given space corresponding to its relative importance and the importance of the industry which it influences. The more common reactions are always given, and if there is anything of particular interest, from a theoretical standpoint, the author usually adds a footnote to bring this to the reader's attention.

In the third division, 257 pages, the real metallic elements are considered. In this section their purification, concentration, general properties, and uses are gone into as fully as space will allow. The metallurgy is quite fully discussed, considering all the more modern methods as in use on the continent, and reviewing those methods that have been set aside by newer improvements.

The book as a whole is a most valuable collection of facts and data. All through the volume the author has introduced very interesting statistics as to the cost of raw and finished products, as applied to continental centers. He carries this further and shows in many cases the eminency of the chemical industries. In this connection, his tables on the world's production of sulphuric acid, soda, and other of the more important chemicals, are most interesting. The materials are arranged in the most logical method possible and all is brought to the reader in a clear, concise manner. All through the volume notes are introduced dealing with some particular

property, or use, for the substance under consideration. Simple tests are often given for determining the purity or strength of the substance, and in some cases complete analytical methods are outlined.

In several cases the author is apparently slightly in error regarding conditions in chemical industries in America. The continental methods are very closely adhered to, giving little attention to any improvement introduced in this country, which has not been adopted abroad. The printing, we are sorry to say, is altogether too small for use in a book of such a character. Many of the illustrations could also be improved upon. But where pages could be written in praise of the book, a few words exhaust the few points that are deficient. W. H.

Practical Descriptive Geometry. By William Griswold Smith, Assistant Professor of Descriptive Geometry and Kinematics, Armour Institute of Technology, Chicago. McGraw-Hill Book Co., New York. 1912. Cloth; 6 by 9½ in.; pp. 208, including index; 132 illustrations. Price $2.00.

At last descriptive geometry has found an exponent who thoroughly believes in linking theory with practice. In other branches of mathematical teaching, the pragmatic tendencies have long been felt, even down to the primary arithmetics, in which men like Speer have demonstrated the decided advantages of working out problems within the practical grasp of the pupil. However, when it comes to descriptive geometry, the subject still is generally approached through long series of theoretical problems,—a method giving excellent results as a means of mental discipline, but one which does not easily hold the interest of the student and which leaves a great deal to be learned by him after leaving school, in the way of applying this instruction. Realizing this, and knowing that applied descriptive geometry enters into many of our industries, Professor Smith has drawn some 200 of his exercises from actual practice, thereby familiarizing the pupil with the application of each problem as fast as he masters it in theory.

In looking over the 210-page volume, one is impressed equally by the pertinence of the cuts, the clearness of the wording, the wide range of practice covered by the various problems, and the judicious use of heavy type as an auxiliary to the indexing. The book certainly marks a decided forward step, and should do its share in enabling students to step more readily and more surely from college to practice. A. S.

Handbook for Highway Engineers. Part I, Theory of Design; Part II, Practice of Design and Construction. By Wilson G. Harger and Edmund A. Bonney. McGraw-Hill Book Co., New York. 1912. 4 by 6½ in.; 493 pages and index. Leather bound. Price $3.00.

This is a very desirable handbook for the use of those engaged in highway work, whether in original planning and construction or in maintenance. The book is small enough to be easily carried in the pocket, yet it contains much that is of use to have on the desk in the office, or on the drafting table. "The book is designed to meet the requirements of both experienced and inexperienced road men." Part I, after an introduction, takes up Grades and Alignment in Chapter I, Sections in Chapter II, and Drainage in Chapter III. Chapters IV to VII inclusive, treat on Foundations for Broken Stone Roads, Top Courses, Minor Points, and Materials, respectively. These occupy 116 pages and contain many convenient tables and illustrations of cross-sections of roadway, drains, culverts, retaining walls, pavements or top courses, etc. There is some valuable information in Chapter VII relating to materials, the testing of stone to show its resistance to impact and abrasion, the use of binders in the surface material (shown to be necessary under the wear and tear of automobile traffic), and concrete materials.

Part II, in Chapter VIII, considers the Survey; in Chapter IX, Office Practice; in Chapter X, Cost Data and Estimates; Chapter XI, Construction; and in Chapter XII, Specifications, including methods of construction.

This book is very timely considering present and growing interest in good roads, as indicated by the various conventions held to further this cause. The book is of value to the educated highway engineer, to the county, township, village, or district officer whose duty it is to look after the public highways, and also to those progressive and intelligent taxpayers who are willing to contribute to the cost of good roads, but wish to have some assurance that their money is being wisely and judiciously expended. Anyone of any intelligence can read the book with interest and profit and upon taking some thought on the various items as set forth by the authors, can better understand the why and wherefore of what is being done and whether it appears to be done according to right principles. W.

The Design of Steel Mill Buildings, and the Calculation of Stresses in Framed Structures. Milo S. Ketchum, C. E., Dean of College of Engineering, University of Colorado. 3rd edition enlarged. McGraw-Hill Book Co., New York. 1912. Cloth, 6 by 9 in.; 556 pages, nearly 300 figures, numerous tables. Price $4.00.

The first edition of this comprehensive work was published by the Engineering News Publishing Co., New York, in 1903, and was noted in our Journal, Vol. IX, p. 220, April, 1904. The second edition was brought out in the summer of 1906, with 100 pages of new text and many cuts. This third edition bears the date of June 1, 1912, and has been further enlarged to a considerable extent with additional matter, illustrations, notes, data, etc., amounting to nearly 200 pages more than in the first edition.

Some of the chapters on Stresses (of various sorts), Specifications for Steel Frame Mill Buildings, etc., have been revised and rewritten. Many of the illustrations have been redrawn. Other additions to the earlier editions consist of certain problems in Graphic Statics and an Appendix III, on Structural Drawings, Estimates and Designs, which contains sundry tables, cuts, and data not readily available.

After a short introduction, a preliminary explanation of a certain classification, the author considers, in Part I, the subject of Loads, as Dead Loads, Snow Loads, Wind Loads, and Miscellaneous Loads. This is followed by Part II on Stresses, beginning with Graphic Statics in Chapter V, next considering Stresses in Framed Structures (Chapter VI), in Simple Roof Trusses (Chapter VII), in Beams, Bridge Trusses, a Transverse Bent, Portals, in Hinged Arches; also of Combined and Eccentric Stresses, with a chapter on Graphic Methods for Calculating the Deflection of Beams.

In Part III is the Design of Mill Buildings—Framework; Coverings; Side Walls; Foundations; Floors; Windows and Skylights, and other details of similar character. The book throughout is a credit to the author and the publishers. The reviewer regrets he did not have such a book at his command in the earlier days of his professional work and considers this new edition as well worth a permanent place among the text-books of the young engineer.

The Primer of Hydraulics. By Frederick A. Smith, Hydraulic Engineer. Chicago, the Author. Cloth. 5 by 7 in.; 217 pp.; 105 figs. in text; 83 pp. tables. Price $2.50.

The author of this useful little book has been for a number of years an assistant engineer in the Department of Public Works of Chicago and had considerable to do with the design of the intercepting sewer system. He is therefore well prepared to write a practical book on hydraulics for the use of working engineers. Designers of experience usually accumulate

tables that shorten their work and which would be equally valuable to other men, not having time to perform the necessary computations. Mr. Smith here presents tables he worked out for his own use and devotes 128 pages of the book to the tables and clearly presented examples of how to use them. His style is good and a student should have no difficulty in working out any practical example in the flow of water with which he is liable to come in contact. Quite the greatest amount of labor in using the Chezy formula is in the computation of the factor "C" by means of the Kutter formula. The author presents 13 tables of "C," with "n" ranging from 0.008 to 0.050. In the first 70 pages of the book he gives concisely the principles of algebra, geometry, trigonometry, mensuration, mechanics, hydraulics, etc., making it a valuable reference manual and a good guide for a man preparing for a civil service examination. No other book is so well adapted for self study on hydraulics, and it is deserving of the title "The" Primer of Hydraulics, instead of "A" primer. Every man engaged in hydraulic work should have a copy. It is well worth the price. M.

LIBRARY NOTES

The Library Committee desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

The Macmillan Co.:
Teachers' Manual of Biology, Maurice A. Bigelow. Cloth.

Frederick A. Smith, M. W. S. E.:
The Primer of Hydraulics, F. A. Smith. Cloth.

P. Blakiston's Son & Co:
Treatise on General and Industrial Inorganic Chemistry, E. Molinari. Cloth.

B. F. Affleck, Affil. W. S. E.:
Proceedings, Association of American Portland Cement Manufacturers, May, 1912. Pam.

F. Shurtleff, Boston:
Proceedings of 3rd and 4th National Conference of City Planning. 2 vols., cloth.

W. W. Curtis, M. W. S. E.:
Annual Report, Bureau of Surveys, Philadelphia, 1898. Pam.
2nd Report of Sewerage Commission, Baltimore, 1899. Pam.

E. E. R. Tratman, M. W. S. E.:
Water Supply & Irrigation Papers, Nos. 289, 291, 295. 3 pams.
Theoretical Treatise on Suspension Bridges (French). Pam.
Outline of Smoke Investigation, Pittsburgh. Pam.
Report of Chief Commissioner, New South Wales Government Railways and Tramways.

EXCHANGES.

New York Public Service Commission, 2nd District:
Fifth Annual Report, 1911, Vols. I & II. Cloth.

New York Public Service Commission, 1st District:
Annual Report, 1910, Part IV. Cloth.
Annual Report, 1911, Vol. I. Cloth.

Colorado State Engineer:
15th Biennial Report, 1909-10. Cloth.

Metropolitan Sewerage Commission, New York:
Report on Present Sanitary Condition of New York Harbor, etc. Cloth.

Institution of Engineers and Shipbuilders in Scotland:
Transactions, 1911-12. Cloth.

Missouri Bureau of Geology and Mines:
The Iron Ores of Missouri. Cloth.

Canada Department of Mines:
Report on the Utilization of Peat Fuel for the Production of Power. Pam.

MEMBERSHIP

Corrected Addresses:

Clausen, H. P., 463 West St., New York.
Fink, J. B., Owasso, Okla.
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Additions:

Aiken, V. H., Fargo, N. D.	Junior Member
Ashdown, E. H., Chicago Heights, Ill.	Junior Member
Blackmer, L. G., Chicago	Affiliated Member
Cadwell, Walter S., Chicago	Member
Cameron, A. H., Minneapolis, Minn., transfer	Associate Member
Dauchy, Samuel, Chicago	Member
Hall, Julius R., Chicago	Member
Lacher, Walter S., Chicago	Associate Member
Musser, Frank S., Chicago	Associate Member
Spengler, J. H., Chicago	Associate Member
Townsend, Robert D., Chicago	Member

Deaths:

White, Henry F., Chicago, October 28, 1912.

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Western Society of Engineers

VOL. XVII DECEMBER, 1912 No. 10

BRIEF REVIEW OF ENGINEERING PRACTICE AND PERSONAL EXPERIENCE IN LATIN AMERICA THIRTY-TWO YEARS, 1880-1912.

Elmer L. Corthell, M. W. S. E.

Presented September 2, 1912.

After four years of strenuous work at the mouth of the Mississippi River, Mr. James B. Eads stood with the author on the sea end of the East Jetty at the South Pass, contemplating the work done and its results,—the nearby channel of over 30 ft. depth where formerly only 9 ft. existed. Satisfied after his wearisome labors by the knowledge that he had given an "open river mouth" to the commerce of the great Mississippi Valley and had opened a new route to the world for its vast products of agriculture, making "bread cheaper to every man, woman and child in the United States and Europe," he looked in imagination across the Gulf of Mexico south by west 800 miles to the Isthmus of Tehuantepec,—less than the distance to Cairo at the mouth of the Ohio,—and said to the author: "Now we must carry the commerce to the Pacific Ocean and the countries on its shores."

This was the birth of the Atlantic and Pacific Ship Railway. Already Mr. De Lesseps had taken up the project of a canal at Panama, and Mr. Eads had given the advice to consider a ship railway on account of the almost insuperable difficulties in the way of a sea-level canal. Later he proposed this to Mr. De Lesseps, but he answered "A canal *au niveau* (or nothing)." As we know, he got "nothing." It is of interest to state here that in 1879, just after the Panama route had been decided upon at the canal Congress, at Paris, Mr. Eads, on June 10th of that year, wrote a letter to the Editor of the *New York Tribune* urging the adoption of a ship railway instead of a ship canal at Panama, which had been estimated at the Paris Congress to cost $120,-000,000, but which when given up by Mr. DeLesseps had already cost $250,000,000, with as much more needed to complete it, and

with \$375,000,000 or \$400,000,000 more to be expended by the United States to build a *lock* canal, and at least \$100,000,000 in addition had a sea-level canal been built. That is, the sea-level canal would have cost, on present plans, nearly \$700,000,000, even deducting from the cost the \$40,000,000 paid by the United States to the New Panama Canal Company for its work and rights.

Just here it is of interest to note that the Panama Ship Railway Company was organized by Mr. Eads and illustrated by a map, profile, and model at the Paris Exposition of 1889, two years after the death of Mr. Eads. From 1880 to 1887 (the year of his decease), Mr. Eads gave his whole attention and unremitting efforts to the realization of his great project. The author went with him to Mexico in 1880 to obtain the necessary concession from the Mexican Government. This was granted with a guaranty of an annual sum of \$1,250,000, with the right to secure similar guaranty for \$2,500,000 from one or more foreign governments, and an invitation to any other country, meaning the United States, to share in the work. The guarantees were to have been effective when a ship weighing 3,000 tons had been transported in safety across the Isthmus from ocean to ocean, 134 miles.

The concession obtained in 1881, somewhat modified in 1885, extended over a period of 99 years. Mr. Eads came at once to the United States Congress asking for a charter on the basis of his Mexican concession, but scarcely two months after the bill was introduced the Nicaragua Canal came before Congress with a somewhat similar measure, with the result that the two projects antagonized each other from the beginning to the end in 1887, a contest of seven years, when Mr. Eads died and his great project was soon after laid aside.

The author, during four years of this period, was engaged in the arduous work of building the New York, West Shore, and Buffalo Railway, as the Chief Engineer of that company, but during that period he had general charge of the Ship Railway surveys and plans, employing a competent corps of engineers on the Isthmus and in New York. After the construction of the "West Shore" he gave his entire attention to the Ship Railway project. It is not generally known how much work was done on this project,—engineering, commercial, and missionary. The route was carefully surveyed under very competent engineers,—Mr. Martin Van Brocklin, who had been the Chief Engineer of the Tehuantepec Railroad, and Mr. D. J. Thayer. Exhaustive surveys were made to find the best route across the divide 700 ft. high, with the best alignment and grades. Work was commenced and officially inaugurated by the officials of the Mexican Government. Mr. Eads had obtained the approval of his principle and methods from the most distinguished engineers, naval

architects, and ship builders in the world. He designed and built a model in London 32 ft. long, costing $10,000, illustrating practically the lifting and lowering, turning and transporting of a model steamship. This model, together with a map of the world 21 ft. long, was shown and operated by the author, with addresses, in several places,—New York; Boston before the Boston Society of Civil Engineers, and the Society of Arts; the Franklin Institute, Philadelphia; the New Orleans Exposition; and for several months in the Naval Committee Room of the United States Senate, and in the basement of the House of Representatives. This model was taken to Paris, as stated above, in 1889 by the "Panama Ship Railway Company," and exhibited in the Mexican section; and it now reposes in dust-covered boxes in its mausoleum in the Department of Communications in the City of Mexico. *R. I. P.*

It became apparent, early in the development of the project, that there was little interest in the world on the subject of interoceanic communication, and that a vast amount of missionary work was necessary, not only in the United States but elsewhere. The author did most of the literary work, which comprised addresses and descriptive matter. A literary bureau was established for the distribution of printed matter. From a record preserved of this work it was seen that over 75,000 copies of pamphlets were distributed to all parts of the world, even to American missionaries in foreign countries; in fact, wherever there could be promoted the most intelligent interest in this important subject of interoceanic communication. In addition to the general subject, Mr. Eads realized that the conversion of the civilized world to his novel plan was first necessary before public opinion and capital would respond to his call for financial assistance. On this work, and the work on the Isthmus and elsewhere in this country and Europe, there was expended over half a million dollars.

Had not the antagonism of the Nicaragua Canal project existed during all this time, and had Mr. Eads lived, no doubt the charter would have been obtained, the money found, and the Ship Railway built, and would now have been in operation carrying ships back and forth between the oceans. The railway was designed to carry vessels of 5,000 gross tonnage, and it was proposed to enlarge and strengthen it for greater loads as they might come. In 1885 5,000 gross tons would have comprised practically all the largest ships of the world. In that year there were only five steamships of a greater tonnage, and they were transatlantic liners.

It is unnecessary to go into the mechanical details of Mr. Eads' plans. The general plan contemplated a wet dock for admitting the ship over a carriage resting at the bottom of the dock

on a pontoon, which would be raised by pumping out the water. When contact was made with the keel and bilges, a complete set of hydraulic rams was actuated, which brought a large number of adjustable supports to bear under the ship, so that she was in effect water-bourne. When the pontoon came up to the level of the rails on the land, a sufficient number of powerful locomotives were coupled on and the vessels transported across the Isthmus. The change of directions was made at three points on the divide by floating turntables. It is of personal interest to state that Mr. Eads was lying very ill at Nassau, New Providence, where he had gone by advice of his physician, from which place he had given instructions to the author to work out the details of one immense hydraulic ram that would lift the entire load on a submerged platform, the hydraulic bearings to remain as in the lifting pontoon plan. He had received the detail working plans at Nassau, and had them spread out before him lying on his bed, when the attending physicians told Mrs. Eads that he could live only a few days longer and that she must tell him this. When told he said: *"I cannot die. I have not finished my work."* Inscrutable mysteries of Providence! He died at almost the very hour when, (through failure to attend to legislation by the member entrusted with the matter, one early morning about two to three o'clock of the closing session of the House of Representatives) the two bills joined by agreement (Ship Railway and Nicaragua Canal) failed to pass. The curtain dropped forever upon both of them and Panama survived, and will soon accomplish the results of several hundred years of efforts.

But Tehuantepec as a route is by no means a back number. When General Diaz had again become President (he was Minister of Fomento—Public Works—when Mr. Eads obtained his original concession), he appreciated the value of the Tehuantepec Isthmus as an interoceanic route, and pushed along the construction of the national railroad of Tehuantepec, which extends from Coatzacoalcos (now Puerto Mexico) on the Gulf of Mexico to Salina Cruz on the Pacific, about 190 miles.

The author had, in 1892, finished his work at Tampico, to be referred to later, and he made a proposition to the National Government to build the harbor works at Coatzacoalcos, which had not at that time been included in any of the concessions. While engaged upon this the Government declared the McMurdo concession for building the railroad forfeited. There was in the national treasury $2,000,000 silver remaining of a $13,000,000 gold bond issue. Silver was at that time worth nearly par. The author made a proposition to attempt to complete the railroad with this residue, and employed a Mexican lawyer, Mr. José Yves Limantour, afterwards Minister of Finance, as his representative before the Government. Unknown to him, Mr. Chandos

Stanhope, an Englishman, had made the same proposition. It was suggested that the two parties should unite and associate with themselves Mr. Joseph H. Hampson, an experienced railroad contractor. This was done in the form of a copartnership, and the author went to the Isthmus to start the construction work. An examination showed that the reports as to the status of the work had been grossly erroneous. Embankments that were reported up to grade, and estimated and paid as such to the contractors, were much below grade, one of them several kilometers in length being 10 ft. below grade. Heavy cuts reported finished lacked 20 to 30 ft. of it. The inspectors misreporting those matters had been put in jail and there was just indignation on the part of the Government. The sum at disposal was not, therefore, sufficient to finish the work. Later, an additional sum was raised by other parties and the rails were connected.

The Government, by a special agreement, had requested the concessionaires to make examinations, surveys, estimates and a report upon the project of building and equipping the harbors on both oceans and improving the railroad, ballasting the track, building more sidings and generally to prepare the line as a truly interoceanic route for a large traffic. This was done, the author having charge of the matter with capable assistants, one of whom was Mr. H. C. Ripley, at present on the Port of Para, and formerly for many years on the Galveston Harbor Works as U. S. Government Assistant. The conditions were that should the Government give the concessionaires the concession covering many millions, they were to do this preliminary work at their own expense, but should the Government give the concession to other parties, the work was to be paid for at cost. The concession was given to other parties, and the author and his associates still have a bill of $15,000 against the Mexican Government, which is snugly lying in a bank box with other "cats and dogs" of that period.

Soon after this a contract was made by the Government with S. Pearson & Sons, Ltd., for the entire rehabilitation of the route, construction of ocean terminals, ample for the large, quick and economical handling of goods from ship to rail and rail to ship. President Diaz told the author in the spring of 1903 that he was making every effort to finish the work, that he would have the start of the Panama Canal by ten years, and that such was the geographical advantage of the Tehuantepec Route over Panama that the traffic drawn to the former in those ten years would be held, so far as it would be naturally tributary to this route.

The route was finished, steamships were arranged for, and the traffic across the Isthmus has exceeded all expectations, be-

ing now over 500,000 tons per annum. It is not generally appreciated how great is the sailing advantage of Tehuantepec over Panama. This will be understood by the statement that the shortest great circle between Panama and Yokohama runs through Corpus Christi on the Gulf of Mexico in Texas, 140 miles *east* of San Francisco, and through the Aleutian Islands. The misconception of this geographical situation is due to the fact that the maps studied at school are on an equatorial projection instead of looking at the world endwise. An examination of any Canadian Pacific ocean route map will show that a detour south has to be made to avoid these islands.

Every steamer from or to the Panama Canal, not only to and from San Francisco but Yokohama, Chinese ports, and even Hongkong, must pass by the very doors of Tehuantepec. The advantage in distance is therefore very great. The distance from Tehuantepec to Panama is over 1,200 miles. The distance from New Orleans to Yokohama is 1,974 miles longer by Panama than by Tehuantepec; from New York, 1,250 miles; from Liverpool, 1,085 miles. In fact, between all Atlantic Ocean ports and North Pacific ports the advantage is with Tehuantepec. While Panama will have the advantage of unbroken bulk, Tehuantepec has such a decided advantage in distance that "Panama will have to reckon with Tehuantepec," as the author has stated in a recent navigation paper.

The author has also had a most interesting work at Tampico on the bar at the mouth of the Pánuco River, seven miles below the City of Tampico.

The Mexican Central Railway in 1889 had completed its railroad from Aguas Calientes on its main line to Tampico, at a cost of $15,000,000, and found itself without an entrance to that river port from the sea. The author was engaged by Mr. Levi C. Wade, President of the railroad, which had obtained a concession for harbor works from the Mexican Government, to make a survey and plans for improvement. The physical and commercial conditions were about as bad as they could be. There was only 8 ft. of water on a stormy shifting bar, which was a veritable graveyard of navigation. At times there was practically no channel at all except a tortuous, unnavigable one to one side. At one time, square in front was an island called "Block Island," appropriately named.

The river at times of heavy rains in the back country on the slopes of the table-lands which rose to 8,000 ft. above the sea, discharges a volume of about 100,000 sec. ft. Careful gaugings in a heavy flood in 1893 gave 150,000 sec. ft. and a maximum flood over 200,000 sec. ft. In times of drought there is practically no discharge. In floods, vast quantities of heavy sediment and debris of all sorts are thrown into the Gulf, which by the sudden

decrease of velocity were dropped on the bar to obstruct navigation. The channel between banks at the mouth of the river is about 1,300 ft. wide. It was desired to obtain 22 ft. depth through the bar, from deep water in the river (about 30 ft. deep) to deep water in the sea. The author laid out his works in two parallel lines straight out to deep water, and 1,000 ft. between centers of jetties. He recommended the extension of the railroad from Tampico to La Barra, and then by a double track trestle or pile bridge out over the north jetty, to be built about 6,500 ft. long, and by a double track trestle over the south jetty, transporting the materials across by a car ferry on a barge towed by a tug. The jetties were made of a hearting of mattresses built in place, suspended from the caps and stringers of the trestle and then dropped into place and loaded with stone from flat cars standing overhead on the tracks. In this way mattresses could be built over 5 ft. thick, and by means of outriggers on the caps and by widening out the trestle near the sea ends, 84 ft. wide. These were loaded with stone and the slopes later on protected with large rock.

The author never for a moment had the slightest doubt of the entire success of the desired full development of the channel, but when, during a long period of drought, the depths did not materially increase, the management of the railroad, the contractor and the resident engineer recommended the building of an interior jetty to concentrate the volume, but the author reported to the president of the company that if the company had half a million dollars to throw away it might do this work, but if it would exercise a little patience the desired channel would come. Not long afterwards rains upon the table-lands and mountain slopes brought down a volume of water that in three days deepened the channel from 17 to 27 ft. Within a short time one of the finest possible channels appeared, straight as an arrow, with a least depth of 28 ft. and with a 24-ft. channel nowhere less than 400 ft. wide.

The principles on which these works were designed and built, as based on the author's previous experience at the mouth of the Mississippi and Brazos rivers, and from extended examination of such works and a study of them elsewhere, were as follows:

1st. Parallel jetties, without curves where possible.

2nd. Distance between them to be equal to that between the banks of the river above, where the channel is the best.

3rd. Projection of the jetties straight out to sea and at right angles to the littoral and wind currents.

4th. Build the sea ends over the bars in the sea in the depth required for the channel.

5th. As broad a foundation as practicable.

6th. Rapid construction to prevent re-formation of the bar in advance of the works during construction.

These principles are correct, as proven by the success attending these works and by failures and disappointments when they have not formed the basis of the works. Two interesting features may be referred to:

First, the temporary protrusion of the bar, due to the heavy sediments vomited out, as it were, by tremendous freshets, the flood discharge reaching at one time over 200,000 cu. ft. per sec. Almost immediately the littoral and wind currents began to cut or shave it off, until, as shown by four relief models exhibited at the St. Louis Exposition in 1904, the amount of deep water in advance of the works in the sea was greater than the survey of 1889 indicated, made before the works were begun.

Second, an inner bar resisted for a long time the erosive power of the accelerated current. A seagoing hydraulic dredge, which had been used on the New York sea channel, was sent to Tampico, and it soon developed the reasons for the resistance. This inner bar was literally filled with sunken wrecks of all sorts of crafts, hulls of boats, sail and steam, loads of heavy machinery, etc. It was the duty of one of the crew to remove, with a tool, the sand from the ledges of the well doors of the dredge, after dumping the load in about 60 ft. of water, and while coming back. On one trip he found two or three silver dollars. On reporting it, the engineer of the centrifugal pump recollected that he heard what seemed to be gravel striking the sides of the pipe while dredging. The dredge was headed for the same spot and began operations, hoping to secure some more dollars. About a dozen were dredged up. Investigations were made of the old records of the port, which revealed the fact that in 1848, during the war between Mexico and the United States, a ship loaded with 60,000 hard dollars for China endeavored to get out to sea, but stuck on the bar and was wrecked, going down into the graveyard which was now being explored by dredging. It was a very disgusted dredge crew who knew that they had dredged up 60,000 dollars, taken them out to sea and dumped them in 60 ft. of water.

The commercial results have been fully as satisfactory as the physical and engineering results. Tampico became almost immediately one of the greatest ports of Mexico. The railroad company at once reduced the freight rates 33⅓%, from all United States and European ports to all interior parts of Mexico, and this reduction was followed by similar reductions on all rail lines entering Mexico and Vera Cruz.

Some details will be of interest: The tides are diurnal, with an average range of 15 in., but sometimes they reach 2½ ft.

During low river the water is quite free from sediment. During floods it is charged with a fine comminuted sediment of which about 18% is silicious, and the remainder argillaceous. The ratio of sediment at such times is about 1/750 by weight. There is no delta formation.

The direction and force of the shore currents depend largely upon the winds. During the season of low water the winds are generally from the north and northeast and are severe and persistent, causing the wave currents to sweep southwards along the coast.

When there are no winds, a true literal current, the Gulf stream current, flows along the coast of the Gulf of Mexico from around the promontory of Yucatan past Vera Cruz to some point north of Tampico, where it spreads out into the Gulf to pick itself up again to rush through the Florida Straits between Florida and Cuba.

The total amount of brush used in the jetties was about 400,000 cu. yd. in place. About 375,000 cu. yd. of rock, about 200,000 lin. ft. of untreated pine piles, about 60,000 lin. ft. of creosoted pine piling, and about 2,000,000 ft. B. M. of timber and planking, were used. Later on, quite a large amount of heavy stone was used in the consolidation and crowning of the stone work.

Prices.

Untreated pine piles driven.........	$0.33	per lin. ft.
Creosoted pine piles driven.........	.60	per lin. ft.
Brush in place......................	1.25	per cu. yd.
Large stone in place...............	2.31	per cu. yd.
Small stone in place...............	1.87½	per cu. yd.

Small stone not to exceed ½ cu. yd.

Large stone not to exceed 3 cu. yd.

Total cash cost of construction, including engineering, was about $2,221,000.

This does not include buildings, railroad extensions to La Barra, real estate, wharves, yard tracks, etc., also general expenses and interest. The entire cost, including the above and all other items, also the cost of the maintenance up to December 31, 1902, was $3,157,690.40.

The total amount of sand scoured from the bar to develop the channel was about 4,000,000 cu. yd. In one flood in 1893, lasting 22 days, the total amount of suspended matter discharged into the sea was 7,500,000 cu. yd. The total amount scoured from the channel, 1,201,000 cu. yd.

The Mexican Government has built at Tampico a substantial wharf half a mile in length, on steel cylinders, costing $3,000,000 Mexican; also a substantial custom house and one nearer the bar.

The commercial results are shown by the following figures:

Exports in 1893, the year after the works were completed,
41,150 metric tons, valued at $8,844,537 Mexican.
1902—167,337 tons, valued at $46,900,359 Mexican.

Imports.
1893—98,242 tons, valued at $2,649,993 Mexican.
1902—541,818 tons, valued at $10,279,068 Mexican.

In addition to these important works, the author's relations to Mexico have been interesting and somewhat intimate with Government and railway officials, as will be seen from the following:

He was quite familiar with the drainage of the Valley of Mexico by examination and study of the maps and other data, in company with Don Francisco de Garay, for many years the Chief Engineer of the Desaque. Assisted by the late Mr. H. W. Parkhurst, M. W. S. E., a survey and report upon a belt railway to connect the various railroads entering the City of Mexico was made. Also an examination and report upon a project of irrigation and power in the vicinity of San Luis Potosi; a report upon the harbor of Altata on the Pacific coast; an examination and report upon the property of the Mexico, Cuanevaca and Pacific Railroad (El Gran Pacifico); and a report upon the harbor improvement of Tuxpan on the Gulf of Mexico. In 1893 he conducted an important negotiation with President Diaz and his Ministers on behalf of an important railroad interest looking to the lease of the National Tehuantepec Railroad for interoceanic traffic.

The author, since the year 1880 first mentioned in this paper, has seen, up to the present date, a most remarkable growth in Mexico on all lines of civilization, education, and development,—railroads, harbors, hydro-electric powers, and street railways and finance. It is to be deplored that the mind that guided that country to its high destiny, and held it steady on its upward course, is now an outcast from his native land. But the time will come when Mexico will remember, and when it shall be too late to restore contentment and satisfaction to him; he will be enshrined in the hearts of his countrymen during all the ages to come, and his statue will grace their plazas and civic places.

Some of the experiences south of Mexico are akin to romances. All are interesting, many are important, but few have been related in any form until now.

In 1885 the late Mr. C. P. Huntington had completed and was operating at a very satisfactory profit the Guatemala Railroad, which climbed to the table-land from San José on the Pacific coast to Guatemala City, the capital of the country. By this route the coffee, equal to any in the world, found its way

to the consumers in other countries. A railroad to reach the same point from the Caribbean Sea at Puerto Barrios had been undertaken, but financial difficulties and political unrest finally compelled a cessation of the work before the line was yet far away from the Atlantic coast swamps.

One of the most interesting figures in Central American history then dominated the situation. Justo Rufino Barrios was then President of Guatemala and the prospective President of the great Central American republic which he was ambitious to form by the consolidation of all the small Central American republics,—Guatemala, Salvador, Honduras, Nicaragua, and Costa Rica. He was a man of extraordinary ability and well fitted to play the role he undertook. He maintained peace and his supremacy by a complete system of militia drill. He had an army of 30,000 men in constant reserve, with nearly 4,000 at the capital, which he made one of the best governed and most orderly cities in Central America. This continued from 1873 to 1885. He built the first telegraph and the first railroad to the sea, compelling every citizen earning over $8.00 per month to hold stock in it. He built street railroads in the capital, improved the roads, built solid bridges, remodeled the educational system, established colleges, and made a knowledge of French and English requisite to practice law or medicine; in fact, he transformed Guatemala into one of the most progressive countries south of the United States. But he failed in the great purpose of his life, which was to unite all Central America into one great state for power and prosperity and to end the miserable wars that wasted it. He finally endeavored to force two of the states that held back, and in the disorders that followed he lost his life, either by a sharpshooter's bullet or by assassination. It was just previous to this disaster that he had written to Mr. Huntington, asking him to send an expert in harbor work to study the conditions at San José, which was an open roadstead at the sea terminus of the Guatemala Railroad, and at Istapa, a few miles east, where favorable conditions were supposed to exist in the form of a lagoon, where ships might find a safe but artificial port. The author was engaged by Mr. Huntington to go to Guatemala, and was making his preparations to sail when the telegraph flashed the news that Barrios had been assassinated. The project ended in his death and it lay dormant until the railroad from the Atlantic had been completed to Guatemala City, and the whole line, now a transcontinental route, was under one financial management. Then the author was requested by the new interests, who probably knew nothing of his previous engagement, to make surveys and plans for making a safe, quiet port at the Pacific terminus of this important line. This was 20 years later, in 1905.

Mr. H. C. Ripley undertook the work and visited the locality, making a careful survey, and returning to New York, where he made the plans in the author's office and in consultation with him.

The proposed port is only 7 miles east of San José along the coast, but 13 miles by a makeshift railroad in bad order that had been built some years before. The lagoon at Istapa is really the receiving basin of the Michatoya River. The lagoon extends along the shore for many miles, separated from the ocean only by a narrow ridge of sand thrown up by the sea to a height of about 14 ft. above sea level. The outlet of the lagoon shifts from place to place, sometimes closing up completely and then breaking out at some new place. At one time, many years previous, a commencement had been made of port works; a trestle had been built into the ocean, and a hydraulic dredge constructed at a cost of $100,000. But work had been abandoned, the trestle had been carried away by the waves, a bridge across the river had been wrecked, and the dredge had fallen to pieces and sunk in the river.

The plan proposed by Mr. Ripley and the author consisted of two parallel jetties built into the ocean at the outlet of the lagoon to a depth of 30 ft. at mean tide level, a length of 750 ft. and 700 ft. between them. They were to be built of stone and protected by concrete blocks. The channel was to be dredged to 34 ft. at mean low tide and extended into the lagoon for an entrance channel. Inside, a basin was to be dredged of the same depth, 500 ft. wide and 3,300 ft. long, and the banks to be revetted with stone. It was believed the jetties would exclude the traveling shore sands from the basin and that the channel would be practically permanent, after the river had adjusted itself to the changed conditions.

The estimate, including a wharf in the basin 2,500 ft. long and 100 ft. wide, was $2,000,000 gold. The author concluded his report as follows: "If the plans we have prepared be adopted, I am confident the works will prove to be permanent and the port prove to be one of the best, thoroughly protected, and of sufficient area as planned, or as may be easily enlarged, for all the commerce that the future may require." The report is dated May 31, 1906. Six years, nearly, have passed and the time of construction has not yet arrived, but when it does there is no reason why a port cannot be built as proposed where ships will enter from the sea into quiet water and tie up to a wharf. The passengers can walk ashore in comfort, and the goods can be landed economically and rapidly and not slung ashore in baskets.

On the sea on the other side just above the line of the Republic of Panama, the author a few years ago made plans for a banana port for a Mobile interest, and sent there his associate,

who had been resident engineer of the harbor works at Tampico,—the late Col. A. F. Wrotnowski, a very able engineer and an educated gentleman. The plans of the banana port were perfectly practicable, but the interests engaged were not able to contend with their all-powerful competitor, the United Fruit Company. While the author has had nothing to do professionally with that great interest, he is well informed of its extraordinary and useful commercial work of furnishing the United States and Europe with tropical fruits. Great plantations were operated, railroads were built into the interior, the most modern wharf and warehouse facilities were furnished, and a systematic business was conducted on a very large scale along the entire Caribbean sea front of Central America and the Fruit Islands.

The author, in passing southwards in his narration, does not wish to avoid the Panama Canal, in which, with all engineers engaged in commercial work, he has had since its inception the greatest possible interest. His work at Tehuantepec, and later, when interested in the Panama Ship Railway, above referred to, made it necessary for him to follow closely the plans, methods, and probable results of ship-canal propositions at Nicaragua, Panama, and at other proposed interoceanic crossings. At Panama the Chagres River and the Culebra Cut have been to him the serious obstacles. At the time when the DeLesseps plans were published for a sea-level canal, he made a careful study of the material in Culebra by means of geological reports, but principally by an examination of the cores of the diamond drills which went to the bottom of this great cut; also by a study of the experience of the Panama Railroad, which only skirted the foot of the slope of the hill. The fact that the railroad had at various times been completely blocked by heavy slides of material, was evidence enough that if a sea-level canal should be made through this ridge, composed of volcanic and variable formations, the side slopes, instead of being 350 ft. high, would run up the east side to nearly 700 ft. and come out in the valley beyond.

The predictions made at that time by the author have been fully verified by the experience of the Isthmian Canal Commission, even at its level of 85 ft. above sea level. There is scarcely any more unstable situation to be found anywhere. No doubt stable slopes will eventually be gained, but the experience has been a costly one.

As to the Chagres River, the present plan overcomes the difficulty entirely by the formation of the Gatun Lake. There is no necessity of hanging this turbulent stream on the slopes of the country or conduct it by tunnels and other artificial channels to the sea to get it away from the canal.

In 1899 the author had a confidential engagement to assist

in the presentation of the Panama case when it was under discussion in Congress. He had made previously a most careful study of the Nicaragua plans, and had long before 1899 become convinced that it would be extremely unwise to attempt to build and maintain a ship canal of large dimensions across that country. It is unnecessary to go into the details, as he is already on record by his published reports.

The author, who with many others had visited the works recently, agrees with the universal opinion, that the work is being conducted in a most admirable manner, and with the greatest possible efficiency and economy. No doubt its operation, if left in the same hands as now, will be equally as satisfactory and conducive to the best interests of the commerce of the world. Two of the greatest navigation facilities will then be in competition,—Suez and Panama (and may the author add Tehuantepec?),—and whatever the result it will be to the advantage of the commerce and industry of the world.

If now we sail from Panama along the "Spanish Main," we will find interesting commercial features with which the author has been connected, and while we, in imagination, watch the buccaneers and Drake and Morgan and the others, we may now find the works of the modern engineer. One of these is at Cartagena, where Putnam, of New Orleans, built an excellent and durable ocean pier of creosoted southern piles. Further on, at the new port of Puerto Colombia, is another long pier, where, at almost any time, can be seen steamers from many countries discharging and loading cargo to be transported to and from Barranquilla on the Magdalena River. From Cartagena it is by rail 60 miles to the river; from Puerto Colombia it is 16 miles.

For over 20 years the author was the engineer of the concessionaires that have had the rights from Colombia to build the works of improvement at the mouth of this great river. For many years previous to 1885 the mouth of the river was open to large ocean vessels to sail or steam in directly up to the Port of Barranquilla. Above that city there is a stretch of river of 450 miles suited to river navigation.

Many years ago Mr. Julius Striedinger, who was one of the best assistants of General Newton at the Hell Gate Improvements, was recommended to the Colombian Government as eminently capable of removing the rocky obstructions to navigation which were found in several places between Barranquilla and the head of navigation. The mouth of this great river became obstructed by shifting sand bars at what is called the "Bocas de Cenizas." After several vessels had been lost and had entirely disappeared, in much the same manner as at Tampico, Mexico, as already described, the open river mouth became a closed river mouth, and landing places along the coast at Savan-

illa, and then at Puerto Colombia and Cartagena were established and rail connections made with the river navigation. Since then it has always been the hope and the earnest wish of Colombia to open the river mouth. There is no question of the entire practicability of accomplishing this by any proper plan. The conditions are fully as favorable as at Tampico or the mouth of the Mississippi, and the cost would not be excessive.

The author, who has made a careful study of the situation during the last 25 years, believes that two parallel jetties straight out to sea with a width of channel between them adequate to carry the volume of the river, would make, and would maintain, a channel for the largest vessels from the sea to Barranquilla.

The personal situation at present is somewhat peculiar. In May, 1907, the author had an intimation that new concessionaires would be likely to come to the United States to obtain engineering assistance in making surveys and plans. In anticipation of this he prepared a detailed letter of instructions to an engineer whom he would send to Barranquilla to make the surveys and bring him the results. Soon afterwards, the author, who was in the United States only temporarily, was obliged to return to his works in Brazil. A day or two before he sailed, the correspondent of the Barranquilla concessionaires sent for him and showed him a letter he had received asking him to find the author and engage him to go to Barranquilla and make the surveys! If he were not available another engineer mentioned was to be engaged. The author could not go personally, but agreed to send a competent engineer to make the surveys and bring the results to him, when he would make the plans, estimates and report, and would agree to take charge of the works. This was not satisfactory. The author sailed. The engineer employed in his place sent the same assistant whom the author had engaged, and who had the author's letter of instructions, and the plans and report were made.

In January, 1911, nearly four years later, the author visited Barranquilla and saw the concessionaires. From them he learned that they had recently engaged the services of a well-known London engineering firm to make new surveys, plans, and estimates. On reaching London the author related to the firm the facts of his connection with this important project covering a quarter of a century, gladly gave them all the documents of any value in his possession, and congratulated them upon having in their hands one of the most interesting and important engineering works.

When financial conditions in Colombia improve, and the credit of the Government becomes reestablished, and its differences with the United States are adjusted, this great work will

go on under the supervision of our British friends, who are abundantly able to carry it through and on correct principles.

In Venezuela the Government, which appears now to be stable, is planning, at least, to greatly improve commercial conditions. Not long since it granted a concession to modernize the capital, Caracas, by introducing an adequate water supply, build a sewerage system, and pave the streets. A navigation concession valued at $10,000,000 to build ports and improve rivers is under negotiation in London. The great river Orinoco is in Venezuela and discharges its silty volume into the sea almost directly opposite the Island of Trinidad, one of the most interesting and prosperous of the British possessions in the Caribbean Sea.

Coming to the Valley of the Amazon the wealth of facts and interests of various kinds,—commercial and industrial,— and developments of marvelous extent, all conspire to bewilder one who wishes to understand the situation. Everything is on such a large scale that even one accustomed to the great plains of the west of the United States and of the development in the Mississippi Valley and the middle west is astonished by what he sees and learns.

The Amazon itself is so much larger than any other river that it cannot be appreciated except by comparing it with our greatest river, the Mississippi. Its drainage area is nearly as large as the entire United States, 2,970,000 square miles. Its high water discharge is over 5,000,000 second feet against 2,000,000 of the Mississippi. If the annual volume discharged into the ocean is considered, it is no doubt five times as great as that of the Mississippi. There are 20,000 miles of navigation, on which over 150 steamers ply. Ocean vessels, mainly the Booth Line from England, of 8,000 tons, reach Manaos, 1,000 miles from the mouth of the river, and ocean steamers of from 2,000 to 3,000 tons reach Iquitos in Peru, 2,000 miles above Pará. At times of high water, ocean steamers can navigate 1,000 miles further along under the eastern slope of the Andes. The U. S. gunboat Wilmington, drawing 10 ft., ascended the Amazon over 3,000 miles.

This great area, especially along the upper tributaries, is the home of india rubber, the product of which is mainly exported through the ports of Manaos and Pará. This rubber product has been the moving cause of important incidents and developments. For many years Brazil and Bolivia disputed the boundary of the Brazilian territory of Acre, where the best grade of rubber is found. The dispute in 1902 had become so acute that the President of Bolivia, General Pando, undertook to drive off the Brazilian frontier guard at the border custom houses. This brought on a crisis, leading, however, to a peaceful and entirely satisfactory settlement between the two countries by the "Treaty

of Petropolis," the summer capital of Brazil, where the treaty was negotiated in 1903. By it Bolivia agreed to acknowledge the boundary claim of Brazil and to develop by railways her great valleys east of the Andes and to connect them with one of the navigable tributaries of the Amazon. Brazil agreed to give Bolivia an equivalent of about $10,000,000 American currency, to initiate this great railway development, and to build and operate the Madeira and Mamoré Railway, 210 miles in length, flanking the 18 rapids of the Madeira River, the principal tributary of the Amazon. The northern terminus of this railway is about 1,700 miles above the Port of Pará, which is itself 65 miles from the Atlantic Ocean. This railway is being built, to be finished this year, by the interests engaged on the Port of Pará. The Brazilian Government furnished $13,000,000 of the construction capital and it has leased the railway to the railway company for a long term of years.

So far there is nothing remarkably interesting in the above statements, but the interest increases when it is known that at the upper terminus of this railway the Madeira River is formed by the conference of half a dozen large navigable rivers, like the spreading fingers of the hand, pouring their immense volumes into this one channel on their way to the ocean, tumbling over cataracts and rapids impassable to anything but Indian canoes for 200 miles. The interest still further grows when it is known that the drainage area and country tributary to the Madeira & Mamoré Railway comprises one-third of the area of Bolivia, a large part of the area of the Great Brazilian state of Matto Grosso, and a part of the rubber territory of Acre, in all an area of about 475,000 square miles, equal to that of Great Britain, France and Belgium combined, lands rich in tropical products of all kinds, especially rubber, cocoa, etc., with extensive herds of cattle and an immense and very abundant pasturage. This last fact has led to the organization of the Brazil Land, Cattle and Packing Company, to utilize for that purpose the nearly 9,000,000 acres of rich pasture lands, mostly in the state of Matto Grosso. This great tract is mostly level, well watered with lakes and streams and a sub-soil water easily reached by artesian wells from 15 to 40 ft. in depth. Cattle can graze in all parts of this area the entire year, with no freezing or storms such as the ranchmen of the west have to fear and protect against.

At present, and in all the past, this great tract has been practically unapproachable. The freight on goods carried on canoes, with laborious portages at the worst rapid requiring a month to go down and six weeks to go up, is practically prohibitive, about $300.00 per ton going down and $400.00 going up. The company is now building a number of large steamers, tugs and barges to operate between Pará and Porto Velho, the

northern terminus of the railway, and suitable stern wheel steamboats to navigate on the 2,500 miles of the upper rivers.

The railroad is not yet in operation its entire length, but will be completed by the middle of 1912. This railroad has had many vicissitudes. Thirty-seven years ago its construction was undertaken under a concession granted to Col. Geo. Earl Church, an American engineer, but after ten years of effort against all sorts of obstacles, political, financial and climatic, disastrous failures came to the enterprise and many of the engineers and contractors died. They were all Americans. It remained for the company, the Port of Pará, also an American interest, to take up the Madeira & Mamoré Railway enterprise, organizing a company under the laws of the state of Maine. The bonds of this company are guaranteed by the Port of Pará. "The Brazil Railway Company," also organized under the laws of the state of Maine, has charge of the enterprise.

It is of interest to know that a member of the Western Society of Engineers, and a former associate of the author when his principal office was in Chicago, Mr. Henry F. Dosé, is now the Chief Engineer of the Madeira & Mamoré Railway and is acquitting himself in his difficult work with great satisfaction to his employers.

The author has gone into this project in some detail as it is a part of very important railway and harbor enterprises, which are transforming the entire republic of Brazil. He refers to the "Brazil Railway Company," which is practically a combination of several important railways in southern Brazil, a great holding company under one interest and, while its other lines have no physical connection with the Madeira & Mamoré Railway, its financial interests are intimately connected with it. The author later on will give interesting data about this railway company.

The Madeira & Mamoré Railway construction and operation were undertaken because of the great commercial advantage it would be to the Port of Pará, of which the author was the Chief Engineer and later the Consulting Engineer, who from the first urgently advised its construction and the operation and navigation of the rivers.

In the year 1903 a restless Austrian traveler who had come up over South America from Buenos Aires on an exploration trip to ascertain if it were possible to find water connection between the head waters of the Paraguay River, which flows south, and one of the tributaries of the Amazon, which flows north, came out at the City of Pará, where a Brazilian held a forfeited port concession based on plans made by a German engineer. Greatly interested in the project, the Austrian traveler came to New York with this concession and the plans and endeavored for many months to find parties who would finance the project.

In 1904 he came, as to many others, to the office of the author and his associates in New York, and his project was "turned down" on account of its defective plans, both constructive and financial. Within a few weeks the author was invited to call at an office unknown to him, where he was asked to say whether he would undertake to make a survey, plans and estimates of a South American port project. He soon ascertained that it was the same project he had rejected a few weeks before. He was told, however, that if taken up it would be with absolute freedom as to the plans, both constructive and financial. On this basis the author agreed to take up the matter, and bethinking himself of his former associate, Mr. Ripley, reached him at Galveston. Mr. Ripley sailed for Para in October, 1904. He made the surveys and went on in January to Rio de Janeiro, where the author met him and between them they made the preliminary plans, which became the basis of a new concession under which the work was undertaken and has been carried on with some modifications up to the present time. Mr. Ripley is still connected with the work, residing in Rio de Janeiro, where he attends to all engineering matters coming before the Federal Government, which has full control and insists upon the right of approval of all locations and general and detail plans, and has its inspector (Fiscal) at Pará to watch the progress of the work.

There are several important ports of Brazil conducted on the same basis,—a concession based on a law enacted in 1869, during the Empire, for the construction and operation of the ports of the country by private companies. That act, approved by Emperor Dom Pedro II, is still in force under the Republic and is the basis of all contracts made by the Federal Executive. In this law are given the general principles that should guide the Government in making the concessions, the presentation of plans, the maximum duration of the concessions, the establishment of the capital, and the provisions for a sinking fund, so that upon the termination of the concession all the works may revert to the Government free of any onus whatsoever. The port dues to reimburse the concessionaire for his outlay are to be approved by the Government. The Para proposition was carefully studied and discussed by the Government. The concession was made, and the contract for construction let to the well known firm of Messrs. S. Pearson & Son, Ltd., of London.

With this relation of the preliminaries, a brief description of the physical conditions and of the work of Para will be of interest.

Para is on its own estuary, although it is connected by deep and navigable natural channels with the main Amazon. The great island of Marajo lies in the mouth of the Amazon. It is 180 miles long and has an area of 15,000 square miles. The

mouth of the main river is not used by ocean navigation on account of shifting sandbars, changeable channels, absence of buoys and lights, and a tremendous "bore" which, at times, produces currents impossible to stem.

The great river Tocantins discharges into the Para Estuary. The city is at the confluence of two rivers, the Guajara and Guama. Deep ocean vessels did not come within four miles of the city piers, which were used by lighters and Amazon River steamboats.

The works comprised a deep quay wall, for vessels drawing 29 ft. of water, and a shallow quay wall for river boats, also a dredge channel from deep water to alongside the quay, and a turning basin.

As the tidal range is about 8 ft. and the wall composed of large concrete blocks from 24 to 30 tons weight is founded on rip-rap resting on hard clay, the whole height from the dredged trench to the coping was about 55 to 60 ft. The space between the quay and the shore has been filled with suitable sand generally dredged by a hydraulic dredge and pumped over the wall.

There are about 4,000 lin. ft. of deep quay wall and 3,000 ft. of shallow wall. Over 6,500,000 cu. yd. of mud and clay have been dredged to make the channel, and 2,000,000 cu. yd. of sand filling have been placed between the wall and the shore. About a dozen steel frame warehouses have thus far been erected and several electric cranes.

The authorized issue of 5% bonds for constructing the works amounts to about $25,000,000. The authorized common stock is $15,000,000, and the preferred stock $17,500,000, a total of $32,-500,000. The business of the port is very satisfactory and rapidly increasing. Its future is assured.

The next port of importance going down the coast is Pernambuco, at the most easterly point of South America and the nearest point to Europe, and from which ships bound for Europe take their course straight to the Cape Verde Islands or Madeira. All steamers stop here. The smaller ones could enter a natural channel lying in front of the city and inside of a coral reef. From this the city gets its real name of "Recife." All large steamers must lie outside and transfer their passengers and freight by lighters, and the passengers often have to be slung on the deck of a little harbor steamer in baskets.

The Federal Government is now building a port with all modern facilities for the largest class of vessels at a cost of over $15,000,000. The work is well under way.

The next port of consequence is at Bahia, where a port to cost about the same amount as at Pernambuco is being constructed.

At Victoria, not far north of Rio de Janeiro, another port

is under construction. While not so large as at Bahia and Pernambuco, it is well protected by nature and does a large business.

At Rio de Janeiro a port work of great magnitude is nearly completed. This is done directly by the Government, but has been leased to a private company to operate. There are nearly three miles of quay wall where the largest ships can come alongside. The space behind the quay has been filled in from one of those numerous hills found in the city.

Rio de Janeiro Bay is one of the most beautiful in the world with its surroundings of high hills and peaks, and its almost entirely enclosed entrance. The bay is of great extent, but until now all loading and unloading was done with lighters and small boats, as there was not one pier or quay wall where a large ship could come alongside. A great area has been dredged near the new wall and the space behind the wall covered with warehouses, electric cranes, and railroad tracks. The cost of the entire work has been about $30,000,000.

In the city itself, with a population of about 900,000, the changes have been almost miraculous. A few years ago the streets were generally narrow and badly paved, the sewerage was not worthy of the name, the general sanitary conditions produced disease, and yellow fever was often prevalent. About six years ago the General Government undertook a complete transformation. It laid out an avenue 110 ft. wide straight through the city from the outer to the inner bay, and also other wide avenues, all paved with asphalt, with wide sidewalks and flanked now by a continuous row of fine buildings, especially along the main avenue. There has also been constructed along the bay a beautiful Esplanade for carriages and automobiles. The street-car lines where the cars were generally drawn by mules, have been transformed into electric cars of American pattern and are operated from a hydro-electric power station, composed of six 9,000 H.P. turbines, located 50 miles distant. These were installed and operated by the Rio de Janeiro Electric Light & Power Company, under the general charge of Dr. F. S. Pearson, the well known American engineer, who had previously installed a hydro-electric power and electric street-car system at the city of Sao Paulo.

Under the direction of Dr. Oswald Cruz, yellow fever has been eradicated by the methods employed at Havana and Panama. He is now applying the same methods at Para. Santos, formerly infested with yellow fever, has also been rid of this pest by the same means, and the health generally improved by good water and sewerage systems.

One of the earliest and best modern ports of Brazil was built at Santos, south of Rio de Janeiro, at a cost of over

$20,000,000. This is the great coffee port of the world, and generally there can be seen steamers from all ports, loading coffee for Europe and the United States.

Further south, between Santos and Montevideo, the Government is building at Rio Grande do Sul a modern port that comprises two lines of jetties over a sea bar, and a modern port inside in the wide and deep channel caused by the outflowing waters of two great lagoons. Of this work the author was the designer as Chief Engineer.

It is interesting to know that in 1876 Dom Pedro II, Emperor of Brazil, came to the United States to attend the Centennial at Philadelphia and to study the works and institutions of the United States. Having heard, from their world-wide reputation, of the attempt of Mr. Eads to open the mouth of the Mississippi River by jetties, he visited the South Pass and was greatly interested in the plans. He asked Mr. Eads to go to Brazil and to there undertake the solution of the question at Rio Grande do Sul, and to make plans for other harbors as well. Mr. Eads' engagements would not permit his acceptance of the offer, but he recommended Col. Milnor Roberts, who did go and made examinations and plans for many ports, including Rio Grande do Sul. He died while performing his duty in that distant country. In 1904 Brazil, then a republic, took great interest in the St. Louis Exposition, and not only sent many interesting exhibits but erected a palace, the facsimile of which in enduring materials stands at the entrance of the beautiful Avenida above described, and its name is the "Monroe Palace."

The Brazilian Commission to the Exposition was charged to arrange for the Rio Grande do Sul work to be undertaken by United States interests. These interests, when conferred with, requested the author to go to Rio Grande do Sul and make the examinations and plans, which he did. Thus, after the 28 years which had elapsed between Dom Pedro's visit to the works of which the author was the Resident Engineer, a visit taken with a view to find some one to undertake the Rio Grande do Sul problem, it fell into the hands of that Resident Engineer, and who has recently given five years of effort to this work and that at Para.

One of the most important developments in Southern Brazil is the consolidation and extension of various railroads under the Brazil Railway Company already referred to. It was formed in 1906, only five years since, with the principal object of uniting and developing as one system the railways that were found in the four states of Southern Brazil, Sao Paulo, Parana, Santa Catharina, and Rio Grande do Sul. Their combined area is 320,000 square miles, with a population now of about 5,000,000. These railways were in five separate systems at the end of 1906,

having no effective junctions or traffic relations and no co-operation in any sense. They now have one system and one management, an interchange of traffic, and a comprehensive system of development which will open up one of the richest countries in South America. The railways thus consolidated or under the direct influence of the Brazil Railway Company, are: Sorocabana Railway Company, Sao Paulo-Rio Grande Railway Company, Parana Railway, Railroad System of Rio Grande do Sul, the Paulista and Mogyana Railways, the Madeira & Mamoré Railway, a line from Sao Francisco proposed to extend west to the Parana River and to Asuncion, Paraguay, and the Teresa Christina Railway in the State of Santa Catharina. The railways worked by the Brazil Railway Company cover considerably over 3,000 miles, and nearly 2,000 miles more are under construction, and in 1,640 miles of lines in addition it holds large interests.

At the Uruguay border, connection is made with a line reaching Montevideo. When the Pan American Transcontinental Railway is completed to Buenos Aires, the Brazil Railway will also reach that city by this new line. There will then be a continuous rail route 1,850 miles long from Rio de Janeiro to Montevideo and Buenos Aires. As stated above, the Madeira & Mamoré interests, united with the Port of Para and Brazil Railway, have immense areas of agricultural and pastural land in Matto Grosso, which is being developed, so in Southern Brazil the Company has 6,000,000 acres of woodland along the lines of the railways in the states of Parana and Santa Catharina, which are being exploited by building sawmills and getting out good pine and hardwood lumber to supply the Brazilian and Argentine markets, which until now were dependent on North America.

The moving spirit and the real head of these vast transportation and industrial interests, and the ports of Para and Rio Grande do Sul, is an American, Mr. Percival Farquhar, who is accomplishing great and beneficent results in this faraway country. The money, however, comes largely from France and Belgium, but the securities of these great works may be found in nearly every country of the European continent and Great Britain.

The staff of Mr. Farquhar is cosmopolitan. As already stated, Mr. Dosé is in engineering charge of the Madeira & Mamoré Railway, the contractors for which, Messrs. May, Jekyll and Randolph, have had large experience in the hot countries and swamp lands of Guatemala and Cuba, and to whom great credit is due for their splendid work in a country that destroyed one excellent organization 37 years ago. But also great credit for the successful completion of this difficult work

should be given to the able corps of medical men trained in the methods of Dr. Gorgas.

One of the leading engineers and members of the Executive Boards of Ports and Railways and other works is Mr. E. Quellennec of Paris, the Consulting Engineer of the Suez Canal, and for many years the Chief Engineer. One of the leading railroad men on the Board of Directors is the very experienced and able railroad manager, Mr. Knox-Little, an Englishman, who was for many years the manager of the Great Western Railway, the principal terminal of which is at Pernambuco, and also late manager of the Leopoldina Railway system, one of the largest in Brazil.

The General Manager of the Brazil Railway is Mr. Frank Egan, an American. One of the most efficient local managers at Rio de Janeiro, and who handles the large matters in Brazil of these various interests, is Mr. Alexander Mackenzie, a Canadian. Another railroad man of large local experience is Mr. Alfredo Maia, a Brazilian, and another Brazilian gentleman of high standing and in charge at Rio de Janeiro of matters with the Governments in respect to Para, Madeira and Mamoré and the operation of the Port of Rio de Janeiro, and who is on the Board of Directors of the Brazil Railway, is Dr. Carlos Sampaio, an educated engineer and a professor in the Government technical school.

Such well-known men as Dr. F. S. Pearson of New York, Sir William C. Van Horne, K.C.M.G., of Montreal, and Dr. Soares, at the head of the important line now under construction to the Paraguay River (600 miles in length)—all experienced and able men—are active members of the Board of Directors, which is essentially an international Board.

In Uruguay the "Pan American Transcontinental Railway Company," of New York City, is building its lines diagonally across this republic from San Luis on the border of Brazil, State of Rio Grande do Sul, and only 35 miles from Bage, the nearest point on the Brazil Railway, to Colonia, on the River Plate, 450 miles, and a branch 40 miles eastward to Cerro Chato, and by car ferry, 30 miles, from Colonia to Buenos Aires, across the River Plate.

At Montevideo an excellent port has been built by the Government for deep-draft vessels. The port is provided with all modern facilities, power cranes, warehouses and railroad connections. This city of 250,000 people is one of the most attractive in South America and one of the best built and most progressive. It has an excellent electric street-car system built by J. G. White & Company, of New York and London, and it should have been stated that this company has built an American system of electric railways in the city of Para.

The republic of Uruguay is on a purely gold basis, and its peso, or dollar, is worth 4% more than the United States gold dollar, having that much more gold in it.

As much of this paper is reminiscent and personal, the author may be pardoned one more reference to his personal experience. In 1898 the Hon. W. I. Buchanan was the United States Minister at Buenos Aires. He had a standing invitation, of which he often availed himself, to dine Saturday evening with the Argentine Minister of Public Works, Dr. Emilio Civit. One Saturday night the latter was relating to the former the efforts the Government had made to gather all possible hydraulic and hydrographic data relating to the three great rivers of Argentine, Rio de la Plata, Parana, and Uruguay, on which they had expended $350,000, and they were then proposing to send to Europe for an expert engineer to come to Buenos Aires to tell them how to improve their rivers.

Mr. Buchanan suggested that some United States engineer would be more likely to have had the experience required for such large rivers, as its rivers were larger than those of Europe and more like those of Argentine, and he told him of the great work that had been done on the Mississippi River, and especially by Mr. Eads at the mouth of that river. The suggestion was approved by the Minister, who obtained authority from President Roca to ask the good offices of Mr. Buchanan to obtain from his Government the recommendation of some expert hydraulic engineer who had had experience in the "Eads Method" of improving rivers.

When the communication reached the United States Government it was referred to one of the leading Government engineers, who was well acquainted with the personnel of Mr. Eads' staff, and he at once recommended the author as filling that specification. This led to his having two years and over of the most agreeable engineering work in his entire experience, high appreciation of his position as the Government Consulting Engineer, reference to his judgment and opinion of many important questions, many of them entirely outside of hydraulics—thirty-four in all—a universal acceptance of his opinion, and always the kindest consideration and generous treatment. Thus again the experience of the author as Resident Engineer of the Mississippi River Jetties was recognized, greatly to his advantage.

When his contract of two years had expired and his work was finished, the same Minister, Dr. Civit, requested him on his return to his own country to "tell the people of the United States something about Argentine," which the author was only too glad to do, and he spent six months—November, 1902, to April, 1903—trying to pay his debt to Argentine by 36 illus-

trated lectures in 30 different cities of the United States, before engineering and geographical societies, Boards of Trade, and popular assemblies from Dartmouth College to Pensacola, New Orleans, Galveston, City of Mexico, San Francisco, Portland, Oregon; University of Nebraska, St. Louis, University of Chicago, Detroit, Buffalo, New York, Brooklyn, etc., etc. The author considers Argentine one of the most delightful countries for climate, one of the best for agriculture, one of the most progressive in railroads, in ports, in water supply, in the civic character of Buenos Aires especially, of any country in the world. And as to education, common and university, it ranks with any.

The port of Buenos Aires cost $40,000,000 gold. It was designed in 1885 for 2,000,000 registered tons of entrances and clearances. It has long reached the 10,000,000-ton mark, and is about to expend $25,000,000 more to build an addition to the port and deepen its entrance channel, 12 miles long, through the mud bottom of the River Plate from 22 to 28 ft. at low water, and to build a channel many miles in length, 25 ft. deep, to the Parana de las Palmas. The great Punto Indio bar, 24 miles wide, lying between the anchorage and the ocean, is being deepened by powerful hydraulic dredges, and by so completely buoying and lighting the course through it on the line of the prevailing currents that the steamships plough their way through it always on the same line, and thus dredge the channel by their propellers as they pass through.

The channels on the Parana and Uruguay rivers are brilliant with gas buoys a long distance above Rosario, 226 miles from Buenos Aires on the Parana River, and to the head of steamboat navigation on the Uruguay. At Rosario the Government has built a $12,000,000 modern port for ocean vessels drawing 21 ft., which visit Rosario for Argentine wheat, which is brought into Rosario by the numerous railroads that converge there. On the ocean every possible point for a deep-water port has been utilized. La Plata, Samborombon (Port Argentine), where a private company under a Government charter is building a deep ocean port opposite Montevideo and outside of the Punto Indio bar; at Mar del Plata, where the Government is now at work on a protected port; at Bahia Blanca, the southern terminal of the Great Southern Railway, and Puerto Belgrano, a naval port in the same great bay of Bahia Blanca.

The Government itself is building thousands of miles of railroads, stretching them as we did once across the Great Plains of wild country to the northwest, and the great railroad companies are extending their lines in all directions. Great systems of drainage and irrigation are being carried out. Sewerage and water works in many cities, where the Federal Government assists the Provincial (State) Governments in improvements.

The city of Buenos Aires is always growing rapidly. It has now a population of about 1,360,000. It has spent over $40,000,000 gold on its water and sewerage works. It is building subways from the center of the city to its principal railway stations.

The Entre Rios and associated railways, long isolated between the Parana and Uruguay rivers, is now in Buenos Aires by means of a 55-mile car ferry down the Parana de las Palmas and a suburban line of the same gauge (4 ft. 8½ in.) built by J. G. White & Company.

Argentine is determined to establish rail connections with its neighbors. The Transandine to Valparaiso is now in operation over the Andes; the road north into Bolivia is under construction. In Patagonia two Government railways are stretching across the Atlantic slopes to low passes leading to Chile. In all directions Argentine is developing.

This brings the author to the end of the story of South America, Central America, and Mexico, so far as he can speak from personal knowledge, but he has not neglected in his investigations the countries on the Pacific. They are not behind those on the Atlantic. Situated with less level country and with the Andes crowding them to the sea, they nevertheless occupy the comparatively narrow sea margin effectively; a strong virile race that knows how and is determined to overcome all obstacles. Chile alone has spent more than $350,000,000 on its railways. It has built two mountain railways to the Bolivian tablelands and Argentine and is now completing the third from La Paz, the capital of Bolivia, to Arica on the ocean.

Peru has built a line from Mollendo on the ocean to Lake Titicaca in Bolivia, and is preparing to build one from the good port of Payta to Iquitos on the Amazon. It is also proposing one from the Port of Callao to Cerro de Pasco and a branch to Iquitos.

Ecuador has buit a line up the mountain slopes to Quito and intends to reach Iquitos via the Napo or Aguarica rivers.

With all the developments described in this paper, perhaps none has greater beneficent possibilities than that on the tablelands of Bolivia, already touched upon. This great interior, isolated in all past ages until now, will shortly be able to send its products downhill to the Amazon, or to Peru, or Chile or Argentine. This great Andean zone of tablelands may be taken at 2,000 miles in length, extending through parts of Ecuador, Peru, Bolivia and Brazil, with a width of 500 miles. Almost any degree of temperature or any desired climate can be found, ranging from tropical to arctic, due to vast differences of elevation occasioned by the Andes. This whole region is sparsely settled, but is capable of absorbing many millions of people

and of becoming a vast field of agriculture, mining, cattle raising, and all the industries. In all railway plans the Pan-American is ever in mind, and link after link appears, always with the ultimate purpose of connecting New York and Buenos Aires.

The author's former quite intimate personal and society relations with many members of the Western Society of Engineers, among whom he spent six years—1887-1893—some of the best of a long life engaged in engineering works, is his excuse for a reminiscent paper full of personal allusions and experiences.

A TALK ON THE PHILIPPINE ISLANDS.

E. L. Lundgren, C. E.*

The Philippines are a group of over 3,000 islands southeast of the Continent of Asia. They lie (between 116° 40′ and 126° 34′ east longitude and between 4° 40′ and 21° 10′ north latitude) wholly within the tropics and almost half way around the world from Chicago.

The commercial route to the Philippines is by the way of Japan and China and is only 1,500 miles longer than the most direct route. On account of loading and unloading freight, stopovers are made in Japan of five to ten days, and in Shanghai and Hong Kong of one to three days, the duration of the journey from Chicago being about thirty-five days. The business men of the Philippines are agitating for a line of steamers to cross directly from San Francisco to Manila. If this could be secured the trip could then be made from Chicago in less than three weeks.

The total area of the Philippines is about 115,000 square miles. This is approximate only, as no accurate map is in existence. The American and Philippine governments are jointly engaged in coast and geodetic work and have charted slightly over half of the islands to date. Strange to say, the coast line of the Philippines is about double that of the mainland of the United States.

The population of the Philippines is over 8,000,000 people, of whom 7,250,000 are classed as Christian and the balance as Mohammedans and pagans. The population in the year 1570 was only 500,000, and in the year 1800 was 1,500,000. Out of the 8,000,000 people only 13,000 are white, many of whom are English, Spanish and German. The United States Army is excluded from this number.

The area and population of the Philippines are about equal to the area and population of Illinois and Wisconsin combined. The difference in economic conditions, however, is very striking. The Filipinos are classed as an agricultural people, but they cultivate only 5% of their area, while we in Illinois and Wisconsin, with a large percentage of our people engaged in manufacturing, cultivate 60% of our area. The rapid growth of vegetation, the antique methods of agriculture, and the legarthic condition of the people, due to living in the tropics, all tend towards an extremely small farm unit. A family of Filipinos will cultivate

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from two to five acres, while here a family will cultivate eighty to one hundred and sixty acres. The Philippine government is making every effort to introduce modern methods of agriculture. In addition to experimental farms and demonstrations of American machinery, the schools devote a large portion of their curriculum to agricultural and industrial work.

The people seldom live on their farms, but congregate in villages for the sake of companionship and mutual protection. During the rice harvest men, women, and children all turn out to work. According to Filipino custom, each head of rice is cut separately by hand and tied in bundles, the pickers receiving one bundle out of every four for their labor.

Fig. 1. Test Boring Rig on Proposed Tunnel, Agno River Project, Province of Pangasinan.

The political organization of the Philippines is similar to that of our government. The executive is called the governor general, the upper house the commission, and the lower house the assembly. The lower house is composed entirely of Filipinos elected to office by Filipino voters. The upper house is composed of the governor general, who is the chairman, and eight commissioners, four of whom are Americans and four are Filipinos. All of the members of the commission are appointed to office by the President of the United States. Three of the American and one of the Filipino commissioners also act as secretaries of departments and receive extra compensation for this work. The entire legislative body of the Philippines is composed of natives, with the exception of the governor general and four commissioners.

In a recent speech before the Chicago Commercial Club, Mr.

Quezon, Philippine delegate to Congress, in his plea for immediate independence, speaks on the injustice of the large salaries paid to the commissioners in the Philippines. He neglects to state that half of them are Filipinos, who evidently feel that they earn the money, as I have not heard of any of them returning a portion of it to the government. He also fails to comment on the fact that the Philippine assembly when elected to office immediately increased their salary from ten to fifteen dollars per day.

President McKinley announced that his Philippine policy was to have the Americans govern the Islands until the time came when the Filipinos were able to govern themselves. This policy is very humane and logical, but has stirred up a storm of protest from the large majority of the Filipinos as well as a large minority of the Americans. The Filipino says that he is now ready to govern himself—that he is afraid that our announced policy is a subterfuge and that we intend, eventually, to annex the Islands to the United States. He feels that he is entitled to the offices that the Americans now enjoy and that he could change conditions to the better advantage of the Filipinos. The American says that we not only conquered the Islands from the Spaniards, but also from the Filipinos, and that in addition have purchased them from Spain for $20,000,000 and have sunk hundreds of millions of dollars into the country since the purchase; therefore it is only logical that the Americans be allowed to exploit the country for their own benefit.

The American administration, in spite of these attacks, had adhered strictly to their instructions as formulated by our late President McKinley. The elective franchise has been rapidly extended to the Filipino voter. First the municipal governments have been turned over to their charge, then the provincial governments, and next the lower house of the legislature. The only steps that remain, before entire self-government, is the power to elect their upper house and their executive.

When this will be done is entirely a matter of conjecture. President McKinley promised it to the Filipinos when they could govern themselves. In the civil service report of the Philippine Islands for 1911 I find there were 3,307 Americans and 4,023 Filipinos employed in 1905, and in 1911 there were 2,633 Americans and 4,981 Filipinos in the service. This shows a decrease of 664 Americans and an increase of 958 Filipinos. At this rate the entire service should be Filipinized in twenty-five years. This agrees with a statement made by President Taft as to the time that should elapse before the Filipinos should secure their independence. Three solutions are possible to the Philippine question, namely, permanent annexation to the United States, immediate independence, and deferred independence.

Annexation is favored by those Americans who think that we, like the larger European nations, should have a trade center near Asia to aid the expansion of our commerce, and in addition, that the Islands could be exploited in a manner similar to the Hawaiian Islands, so that the United States would be compensated for the enormous expenditures we have made in the Philippines.

Immediate independence is favored by a vast majority of the Filipinos as a national instinct. No race cares to be governed by another race, no matter how paternal the government. It is also favored by a large percentage of Americans, who point out that the cost of the Philippines to the American taxpayer is

Fig. 2. Scene on the Benguet Road After Storm.

During this typhoon the world's record for rainfall was broken; 34.5 inches in one day, and 88 inches in four days, at Baguio, Province of Benguet, Philippines.

between ten and fifteen million dollars per year in addition to what it would cost if all of our army was kept in America. They claim that our manufacturers cannot supply the markets on our own continent for many decades and that the Philippines would be a source of weakness in time of war.

Deferred independence is the present policy of our government and will continue to be unless the American voter determines otherwise. The governor general and the commissioners, in view of the opposition of those who do not agree with their instructions, deserve great credit for the tact and skill with which they are doing their work.

In consequence of this policy, the Philippines have a complete government organization which is distinct from that of the

United States. Their laws, postage stamps, and currency are entirely different from ours.

The Philippine civil service employs a large number of Americans in various capacities, but they are being replaced as rapidly as Filipinos can be educated for the offices. Ultimately all of the Americans will be replaced by Filipinos, so when they receive their independence there will be no confusion in the government due to Americans leaving the country.

The government shortly after it was reorganized by the Americans placed the currency of the country on a gold basis, arbitrarily making the peso equal to half of an American dollar. The coins issued are similar to ours, but are worth only half as much. They are the centavo (a copper coin about twice the size

Fig. 3. Method of Throwing Up Earth Embankments in Swampy Ground.

of our cent), the five centavo (a nickel coin the exact size of our five cent piece), the major peseta (a silver coin similar to our dime), the peseta or twenty-centavo piece (this fractional silver coin is more convenient in making change than our twenty-five cent piece), the major pesos or fifty centavo piece, and the peso, or one hundred centavo piece (silver coins similar to our half dollar and dollar). Paper currency only is issued for money above a peso. These bills are much smaller than our American notes, being only two-thirds as long and two-thirds as wide. This smaller size is found more convenient to handle than the larger American bills.

The only postage stamps that can be used in the Philippines are those issued by the Philippine government, which fact does not seem to be understood in the United States. Practically all who have dealings in the Philippines send their addressed return

envelopes and cards with American stamps on them, losing thousands of dollars annually from this item alone. Much better results would be obtained if Filipino stamps were placed on the return cards or else a statement of the denomination of the Filipino stamps necessary to mail the return card.

The Philippine government collects the customs and internal revenue in the Islands and the proceeds go into the Philippine treasury. The United States receives no revenue from the Islands.

The engineering work in the Philippines is mainly under the supervision of the Bureau of Public Works. This bureau has charge of the construction of roads, bridges, public buildings, artesian wells, irrigation systems and river control works except in the city of Manila, which has its own engineering department. The bureau of navigation has control of the construction of port works and lighthouses.

During the last four years the personnel of engineers of the Bureau of Public Works has increased from 50 to 110 and its expenditures from one million to five million dollars per year. The average length of service of the engineers is about three years and the average annual salary is about $2,000.00. On June 30, 1911, the total number of employees was 1,489, an increase of 27% over the preceding year. Of this number 564 were Americans and 925 Filipinos. These figures do not include laborers and native foremen hired on force account.

Over $3,000,000 is now spent annually on public roads. On account of climatic and traffic conditions the deterioration of a high grade macadam road in the Philippines is exceedingly rapid, the rate of deterioration being about 25% per year. In other words, four years after a road has been constructed it is practically impossible for wheeled traffic. The Spaniards were good road builders and the remains of their work can be seen all over the Islands. The United States Army, while it administered the country and later the Philippine government as organized by the Americans, spent large sums in road construction, but as fast as new roads were built the old ones went to pieces. Sledges were in common use and on most of the carts the wheels were narrow rimmed and were fixed solidly on the axle.

(The accompanying illustration shows a typical cart as used in the Philippines today. In Spanish times the wheels were a solid section cut out of wood and set solid to the axle, with very narrow rims; the Americans have taught the natives how to manufacture cart-wheels with broad rims, such as are used in the United States. Chinese coolies are shown unloading sugar molds. The carabas or water buffalo is harnessed to the cart by a yoke and is guided by a rope tied through the nostrils;

a long, steady pull on the rope turns him to the right and a series of jerks turns him to the left.)

In 1908 a new road policy was inaugurated. Sledges and narrow rimmed vehicles were not allowed on improved roads. The 237 miles of good road that then existed were put under maintenance. One laborer working constantly on each half mile was found to be necessary to keep the road in good condition. This work consists of filling up ruts with surfacing material, cutting down tropical growth, cleaning side ditches, etc. In addition, it is necessary to completely resurface the road every five years. The expense of this maintenance has been found to be about $500.00 per mile per year, and as the cost of construc-

Fig. 4. Typical Cart in Present Use in the Philippines.

tion varies from five to ten thousand dollars per mile, the deterioration of improved roads under the present system, as measured in cost of upkeep, is only from 5% to 10%, as compared with 25% under former conditions. Since this system has gone into effect, the mileage of first class roads has increased from 237 miles in 1908 to 950 miles in 1911.

The Bureau of Public Works has completed plans to construct a road from one end of Luzon to the other, and hopes to accomplish this important work in the next two years. A very thorough study has been made of the roads needed for the economic development of the Philippines. From this study proposed road construction has been laid out so as to build roads that will benefit the greatest number of people. By this I do not

mean that roads are to be built only in congested areas, to the neglect of the more sparsely populated districts, but it is the intention to spend the money in a direct ratio with the density of the population throughout the Philippines. This has led to the construction of a large number of disconnected stretches of road, generally out of each provincial capital, which is usually the center of commerce for the province. All work is being done with the complete road system in view, and no deviation from this plan is permitted.

Wood, on account of its rapid decay in the tropics, has been abandoned for bridge construction, and reinforced concrete is now used almost exclusively.

A district engineer is stationed in each province and has

Fig. 5. Gaging Station on the Agno River; Span, 680 Feet.

charge of the construction of the public buildings and roads in that province. He may have one or more assistant engineers, depending on the quantity of work to be done. Most of the culverts and roadways are built by force account, while the bridges and public buildings are mostly constructed by contract under the supervision of the district engineer.

The various provinces are combined into five divisions, each under a division engineer, who inspects the work of the district engineer and sees that construction is kept up to the standard set by the chief engineer of the bureau.

Irrigation and river control work is executed by another division of the Bureau of Public Works. The work is done under

the immediate supervision of a project engineer, who reports to the chief irrigation engineer of the bureau. The funds for irrigation work are provided by special act and the plan is to have the benefited parties reimburse the government for the work done.

The irrigation division was organized in 1908. The engineers found that nothing was known as to hydrographic conditions and that no contour maps were in existence. First various

Fig. 6. Trail Made by American Engineers Over the Mountains. The rapidity of growth of vegetation may be judged by the length of the grass in the foreground, which was cut one month previous.

projects were roughly blocked out, gaging stations established, and reports with approximate estimates were made. From these reports it was decided whether the project should be abandoned or whether detailed surveys should be made. A few small projects were found to be so favorably situated that constuction

was begun immediately after the surveys were completed, but on the larger projects the collection of hydrographic data for at least five years was deemed essential.

(In Fig. 5, is shown a gaging station on the Ango River. The span is 680 ft.; the main cable is ¾ in. in diameter, while the tag and stay lines are ⅜ in. The more vertical leg of the A-frame is the trunk of a tree that was growing on the spot. Gagings were taken by an American hydrographer who visited the station,

Fig. 7. Bridge on the Benguet Road.

weekly, while a Filipino gagekeeper lived in the vicinity and read the river and rain gages twice a day.)

A vast quantity of information has been collected to date. More than 200 projects have been considered, of which over half have been abandoned as not feasible. Final construction surveys have been made on five projects and construction is expected to commence on the completion of the hydrographic studies.

An artesian water supply was discovered about five years ago and the drilling of wells for municipal water supply has become an important branch of the Bureau of Public Works. The benefit of improved drinking water is shown by a rapid decrease in the death rate wherever an artesian supply is secured.

About 120 miles of railway were in operation when the United States conquered the Philippines. The Americans have made successful efforts to increase this mileage; 414 miles were in operation in 1908 and 585 miles in 1911, an increase in three years of 171 miles. 698 miles of proposed construction have been authorized by the Philippine government and ultimately the Islands will have a very complete system of railways.

Fig. 8. Interior View of Wall Around the Spanish City of Manila, Showing Gate and Dungeons in Wall.

The friar-lands question has received a great deal of attention from Congress, and has become a matter of interest. The friars consist of a number of orders affiliated with, but at the same time, entirely distinct from the organization of the Catholic Church. At first these orders gave great assistance to the Spanish government and were the prime factor in civilizing the Filipinos. Naturally they gained the respect and good will of both the natives and the government and they were deferred to by all. Unfortunately this taste of power was demoralizing and the orders became greedy for more power and luxury. They became so powerful that they could unseat the governor general at will. Conditions became so bad that the Spanish king expelled the

Jesuits and only allowed their return many years later under very restricting conditions. At the time of the American occupation the four orders of friars who were allowed to possess property were the Augustinian, having 346 friars in the Philippines; the Franciscan, having 107 friars; the Dominican, having 233 friars, and the Recoletos, having 327 friars. They were able to show title to 420,000 acres of land.

The friars are said to have acquired title to these enormous holdings in a questionable manner. This matter was a source of constant friction between the Spaniards and the Filipinos and appears to have been one of the main causes of the various insurrections against the Spaniards. In order to settle the matter Congress authorized the Philippine government to purchase

Fig. 9. Street Scene in Manila, P. I. Bureau of Printing in Background.

the land for the purpose of resale to actual residents; 410,000 acres out of the 420,000 acres were purchased for $7,239,000. Practically all of the cultivated area has now been disposed of. A large portion of the land, however, was found to be unsettled and when they were unable to sell it to individuals the government began to sell the land to corporations in large tracts. Congress was informed of this and stopped the sales. The Philippine government has this property on hand and is unable to sell it as Congress desires, so they now advance the argument that the American government should pay for this land in order that the bonds may be retired.

The friar lands should not be confused with the lands of the

Catholic Church. The church also has enormous holdings, but they were not purchased by the government.

Tourists arriving in Manila will find it one of the most interesting cities in the world. In modernizing the city the Americans have made every effort to enhance the beauty of the old mediæval city they found instead of destroying the old scenes, as is usually done.

Mr. D. H. Burnham, of Chicago, was called to the Philippines by the government soon after it was organized and drew up the plans for future improvement of Manila on the same principle as the proposed City Plan of Chicago. While there he also visited the site of the proposed summer capital at Baguio and drew up a tentative plan for construction of that city.

One of the most interesting features was his treatment of the old walled city. Paris replaced her walls by a beautiful boulevard, and in one way or another most of the walled cities of the world have disappeared. Manila, however, has hers intact and the space formerly occupied by the moat has been filled in and made into sunken lawns similar in appearance to our Midway Plaisance. This not only brings out the full effect of the old fortifications, but creates a large playground, where hundreds of Americans and Filipinos play baseball, association football, and other games in the afternoon, attracting thousands of spectators.

The harbor problem was solved by building a new breakwater and dredging a new basin, the excavated soil being used to fill in the old moat and for making new land along the water front. The new fill is used mainly for warehouse and harbor facilities.

Another interesting feature of the Sapnish occupation is the Luneta. This is a small park and driveway where the people of Manila assemble in the evenings and listen to the music of various military bands. This glimpse of Manila on dress parade is a sight that I do not think is ever forgotten by one who has seen it. To give this feature a better setting and to provide space for the government center, Mr. Burnham planned to have it moved to the new fill.

DISCUSSION.

J. H. Warder, Secretary: I will ask Mr. Lundgren if the gates through the wall (Fig. 8), were closed by any movable construction like an iron gate, or were they always open?

Mr. Lundgren: During Spanish times a portcullis was in use. The openings and remains of the apparatus which the Spaniards used to close the gates can still be seen.

Mr. Warder: Then the openings could be entirely closed against any invading force.

Mr. Lundgren: Yes, that could be done.

Mr. Schuchardt: As to health conditions in the Philippine

Islands, are there any mosquito troubles, or troubles similar to those in Panama?

Mr. Lundgren: The Americans are improving conditions in the Philippine Islands, as they have done in the Panama regions. Manila is situated in a swampy, unhealthy locality, and in erecting buildings two or three feet of dirt must be filled in, as a rule. The Americans have spent a great deal of money in draining this low land. Rice paddies surround Manila, and in growing rice it is necessary to keep the paddies flooded with several inches of water, so the local conditions are difficult. In my experience the number of mosquitos has decreased enormously, but we never think of sleeping without mosquito-bar protection.

The death rate, if I remember correctly, is about fourteen among the Americans and white people, and about thirty to thirty-five among the Filipinos. Of course, the Americans on the Philippine Islands are all picked men. The government would not think of sending a man to the Islands unless he was in good health, and possibly that is one reason why the death rate is as low as it is. The death rate among white people compares very favorably with the death rate in the United States.

President Armstrong: What is the necessity of irrigation, considering the heavy rainfall? Is it on account of a distinct rainy season and a distinct dry season?

Mr. Lundgren: The way the Filipino cultivates rice, he must have several inches of water on the rice paddy practically the entire time that the rice is grown. This water is not allowed to become stagnant, and is slowly flooded through the paddy. The rice is not planted until there is plenty of rain and the paddies are flooded, but when the rice is "in the milk," as we call it there, it is about the end of the wet season; a few weeks of dry weather at this time reduces the crop materially. About twice in five years they get a 50% crop, and about once in five years they lose the crop altogether, in spite of the enormous rainfall. When figuring these losses, the advantages of irrigation can be seen. An additional advantage of irrigation is, the Filipino can raise another crop during the dry season if he is so inclined.

President Armstrong: What is the character of the materials used for the concrete work mentioned?

Mr. Lundgren: We are forced, on account of poor transportation facilities, to take the rock that exists in the neighborhood. Most of the stone, or practically all of it, through the Philippine Islands is of a very soft character.

Mr. Warder: Is it something like limestone?

Mr. Lundgren: There is some limestone, but much of the stone is andesite.

Mr. Warder: Is that a volcanic rock?

Mr. Lundgren: Yes. The Spaniards did most of their constructing with adobe, which is really a hard clay. After it is quarried

and shaped, it slowly hardens and becomes a fairly durable material, if the walls are made thick enough.

President Armstrong: Referring to the illustration of those walls, some of them seemed to be quite a large mass of stone; is that adobe?

Mr. Lundgren: Yes, that is adobe.

President Armstrong: That is a different material from the adobe of Mexico, isn't it?

Mr. Lundgren: The adobe of Mexico, as I understand it, is a baked clay, but this is a natural formation that is quarried and used in the Philippines.

F. G. Munoz: Did not the Philippine legislature pass a law limiting the amount of friar land sold to a corporation to 2,000 acres? Isn't that what caused the investigation by Congress?

Mr. Lundgren: I am not very well posted on the question of legislation, but I think the American Congress passed a law that the Philippine Commission could not sell this land in large tracts.

Mr. Munoz: I thought the Philippine legislature passed a law, limiting the amount of the land to 2,000 acres, so that the sale of these lands should not be in large quantities, in order to protect themselves from corporations. I am not positive about the figures, however.

Mr. Lundgren: It is my understanding that the Philippine government wants to get rid of this unoccupied friar land in any way that it can, so it may refund the Friar Land Bonds, and the Congress of the United States has prevented this being done. Full information on this subject may be obtained from the reports of the Philippine Commission, on file in this city at the Crerar Library, and also in the library of this Society, but I can state positively that the Philippine Commission is protecting the rights of the Philippine people.

WIND PRESSURE ON BUILDINGS

ALBERT SMITH, M. W. S. E.

Presented October 7, 1912.

In November, 1910, the writer discussed, before this Society,* the common methods of applying wind loads to mill buildings and other covered structures not braced by intermediate floors. In his discussion of this subject the writer advocated the consideration of the suction effect of the wind on the leeward wall and roof, as tending to reduce the sections of columns and girts from those derived by rigidly applying the assumptions now in common use, and at the same time increasing the sections of certain of the truss members. The basis for an assumption as to the amounts of the normal pressures and suctions on such structures was the work of Irminger, of Copenhagen, confirmed and elaborated by Stanton, of the British National Physics Laboratory. The reliability of a series of loading assumptions derived from the work of these men was uncertain, not because of any lack of accuracy in the experiments, but because the experiments were performed in an artificial current of air and upon small models whose only shape variation was in roof slope, and whose dimensions were unreported.

It is, obviously, of the first importance to base practical assumptions upon experiments performed in the open air,—that is, in an air channel of infinite cross section,—and upon such a number of models as to show the influence of the shape of the building upon the distribution of the pressure.

In the fall of 1911 the writer laid out the plans for the model building shown in Plate III and the pressure-reading apparatus shown in Plate I. It will be noted that the model building has three different roof-slopes, auxiliary base sections which give three height variations, and is built in two length sections, giving three different lengths of model. In all ,then, there were twenty-seven different models used. While the range of three variations is not a large one, it was expected that the variations of distribution due to shape would be fairly regular, and that three would suffice.

It was regarded as certain that the maximum wind effects would be found at the middle of the longitudinal dimension of each model, and it was accordingly determined to test three points in each wall and each roof-slope at this section. Some of the models with 5 ft. and 6 ft. height of wall were tested at four and five points in the wall.

Small holes were bored in the wall and roof, and a brass nozzle

*Journal, Western Society of Engineers, February, 1911.

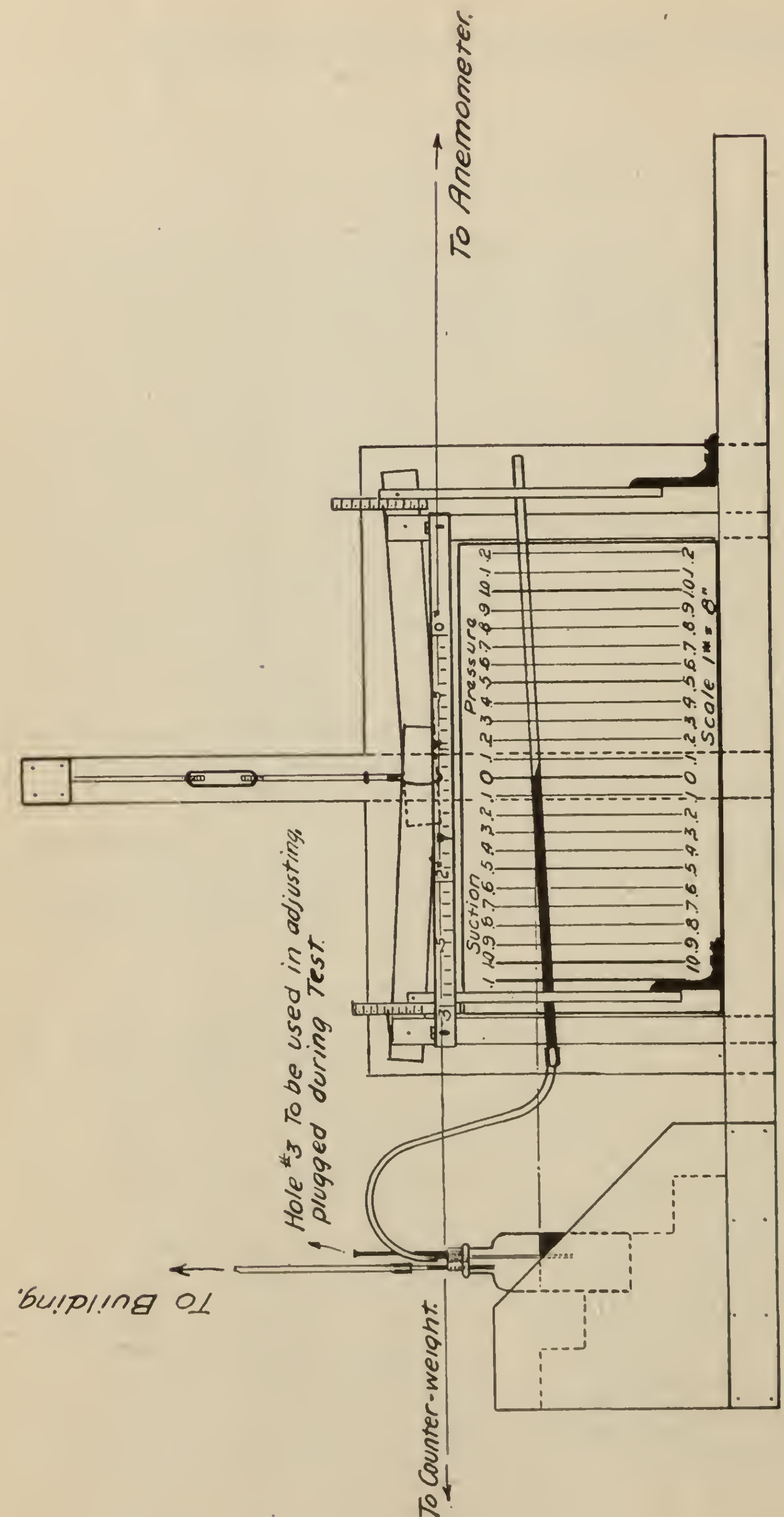


PLATE I.

PRESSURE READING APPARATUS.

NOTE: Apparatus Complete Consists of a Battery of 17 Tubes and Bottles. ½" c. to c.

was screwed into each hole, flush with the outside surface. On the inside end of each of these nozzles was attached a piece of ⅜ in. rubber tubing. These rubber tubes led, by means of a glass tube, through a rubber stopper into the air contained above the surface of the liquid in the bottles. (See Plate I.) By means of a rubber tube syphon, the liquid in the bottle was connected with the liquid in the glass tube shown in front of the scale. When the air pressure inside the bottles was the same as the air pressure in the end of the long glass tube, that is, the air pressure inside the building, the level of liquid was the same in the bottle as in the tube. If, however, during a wind, either pressure or suction was produced at the end of the brass nozzle in the wall, that pressure would be communicated to the surface of the liquid in the bottle. The level of the liquid in the long tube would then either rise or fall, and the amount of this rise or fall would be proportional to the amount of the pressure or suction exerted.

Seventeen such bottles and tubes were provided for originally, but only sixteen were installed. The tubes were placed in a vertical rack and were spaced accurately on ½ in. centers. The bottles were seated on sixteen small steps whose height varied by ½ in. Four were placed in one row, so that the end steps, shown in Plate I, have a 2 in. difference in height.

The heights of the ends of the tube rack were controlled by two horizontal levers whose positions were adjusted by means of the turnbuckle shown above the center of the rack. It is needless to say that great care was used to make the respective arms of these levers exactly equal. The liquid was then introduced into the bottles and syphons until the upper edges of the meniscuses of the liquid in the tubes were all brought exactly on the vertical line marked zero. (See Plate I.) The line of the meniscuses in the tubes should then remain vertical for any slope of the tubes produced by the turnbuckle. In practice it was found that this was the case, except for slopes very near the horizontal. All the readings were taken with a slope of 0.024 in 1, but the turnbuckle adjustment was used in order to be able to take readings in a 40 or 50 mile wind, if one should occur. The line of meniscuses was very nearly vertical for a slope as small as 0.01 in 1, but no attempt was made to utilize a wind requiring such delicacy.

While the apparatus was being set up, and during the first tests, there was some danger from frost, so that the tube rack had to be very carefully adjusted for level. This also made it necessary to use a liquid with a low freezing point. The liquid used was the water from the West Lafayette water works system, mixed with alcohol in the proportions of two to one.

The intensity of the pressure indicated by any given reading was determined as follows: Calling the fall of the liquid in the bottle H_1, and the rise in the tube H_2, and the scale length for 1 lb. pressure L,

Difference of level for 1 lb. per sq. ft. = 12/62.5 x 0.95 = 0.202 in. where 0.95 is the specific gravity of the alcohol and water mixture.

$$\frac{L \times 0.21^2 \times \pi}{4} = \frac{H_1 \times 2.1^2 \times \pi}{4} \text{ or } H_1 = 0.01\,L$$

where 0.21 is the diameter of the tube, and 2.1 is the diameter of the bottle.

$$0.202 = L \times \tan\ \text{slope} + 0.01\,L$$

$$\text{Tan slope} = (0.202/L)—0.01.$$

The probable useful slope was estimated to be such that 1 lb. = 8 in., giving tan slope = 0.202/8—0.01 = 0.015.

With the tubes inclined at this slope, pressures could be read directly on a scale laid out to 8 in. = 1 lb. per sq. ft.

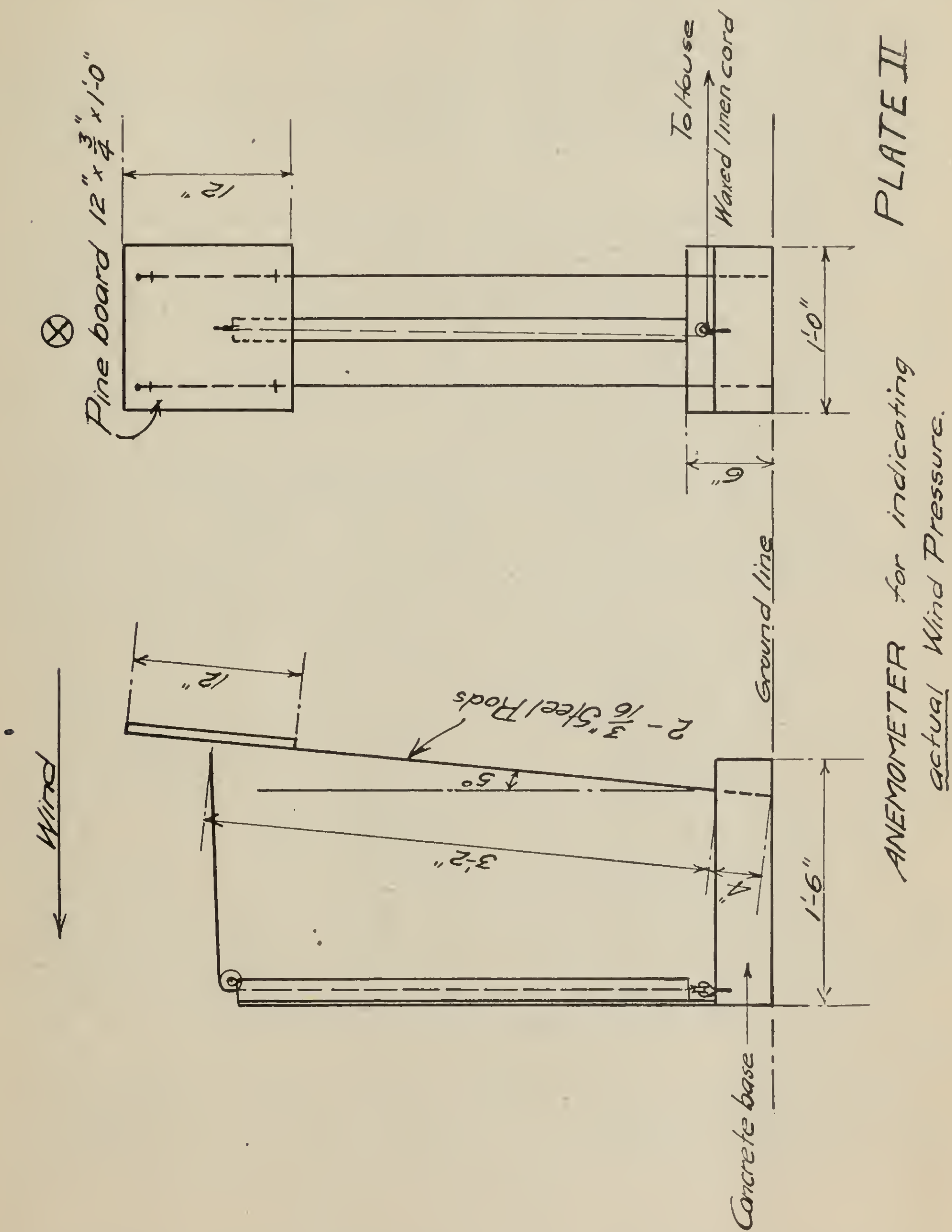
When the first readings were being taken, it was demonstrated that with a slope of 0.015 the readings for some points of the model would not lie within the visible part of the tube during a wind exceeding 20 miles per hour. The tubes were accordingly adjusted to a slope of 0.024, but no second scale having been provided, the readings were taken with the 8 in. scale.

The original plan was for an apparatus without errors, which should show the true pressures at each point in the model by reading on the pasteboard scale behind the tubes. It was found, however, that the instrument, when put together as well as seemed possible at the time, contained tubes and bottles of varying diameter, and that some of the tubes were curved in the vertical plane. Since a correction was necessary for each reading before the results were diagrammed, it was thought just as well to let the observations taken with the 8 in. scale stand without repetition, and to take the rest of the observations with the same scale. The correction factors are discussed under the heading "Correction of Data."

THE PRESSURE INDICATOR.

On the sample records will be noticed a narrow horizontal scale, above the tube scale, and in front of this scale will be seen a small triangular pointer. This scale gives pressure in pounds per square foot on a thin plate exposed at the end of the building. The pointer is carried on a thread running over pulleys at either end of the tube rack. At the left end the thread, after passing over the pulley, carries a small counterweight. At the right end the thread is carried around pulleys, out of the house, to the pressure indicator. The pressure indicator itself is shown on Plate II. Two 3/16 in. steel rods were imbedded in a heavy concrete base. A pine board, whose area was 144 sq. in. for moderate winds (72 sq. in. for high

winds), was attached to the upper ends of these rods. This target was so placed as to be at about the average height of the exposed surface of the models. From the target a thread led over a pulley down a covered channel and into the house. On a very still day the



indicator was calibrated by hanging weights varying from 0.1 lb. to 1 lb., on a thread running from the target over a special pulley set up for the purpose. This latter pulley was about 3 in. in diameter, to reduce the friction to a small quantity. A great many trials were

made, going up and coming down the scale, to determine the scale length for 1 lb. pressure, and the resulting determination is believed to be without any appreciable error.

This contrivance undoubtedly has some inertia, and will read too low at the beginning of its motion, a fault which it shares with the tube indicators, but it will also read too high at the end of its motion, which the other will not do.

The pressure indicator was designed to furnish a comparison of thin plate wind force with the forces on the building surfaces at the same instant. There are three conditions which tend to vitiate its showings:

(a) The velocity of the wind which hits the target is greater than the velocity which is producing forces on the model. A large object produces such an increase of wind velocity around its edges that a small target exposed quite near to the large one will have a much greater unit force.

(b) Since the size of the model varies very greatly, the ratio of these velocities cannot be constant.

(c) A very slight deviation of the angle of incidence of the wind from the normal to the side of the building produces a very large change in the amount, velocity, and direction of the air flowing around the ends of the building, and hence on the target unit-force. It was not possible to be sure that the wind during a test was not as much as 10° away from the normal, though with care we could be fairly sure that it was not more. From the results of Stanton's and Duchemin's tests on inclined plates, we are justified in inferring that the pressures on the buildings are not appreciably affected by a small variation in the direction of the wind, but increased or diminished amounts of air striking the target will evidently greatly affect the pressure-indicator readings.

The obvious remedy for these defects would be to remove the target to such a distance that the eddy around the end of the building would not affect it. It is not certain, however, how far out from the building the pressures during a gust may be regarded as uniform.

In future tests it will be necessary to get thin plate pressures some distance in front of the building by means of an observer stationed in a pit.

The observations on thin plate pressure taken during these tests are, perhaps, interesting, but quite valueless for comparison with the building forces.

RECORDS.

The original records consist of photographs taken of the instrument within the building while the wind was blowing. To make this possible the liquid was colored with a small quantity of safranin. After some trials, the least quantity which would make a clear photograph was determined, and it was found that this mixture did

not stain the tubes badly during the tests. The rise of the liquid in the tubes was observed to lag somewhat behind the variations of the wind intensity, due to the damping effect of the water column. Care was taken in selecting the instant for exploding the flash light after the rapid increase of velocity of the gust had ceased, and before the correspondingly rapid decrease had begun. The pressure indicator, whose reading appears in the horizontal scale above the tube rack in all the records, which was quite sensitive to changes of velocity in the wind, furnished an excellent guide as to the proper time to set off the flash. This condition existed when both the pressure indicator and the meniscuses of the liquid columns were as nearly as possible at rest. In all cases two photographs were taken of each model shape. This was done to guard against a failure of the camera, and to furnish a check record of each shape with a wind of different intensity. Altogether, for ten of the twenty-seven model shapes there is only one good photographic observation. The intention of repeating these observations afterward was given up, because on comparing the duplicates in the other seventeen cases, it was found that the relative lengths of the tube readings remained almost exactly the same, even where the difference in wind velocity was large. After this comparison, if two photographs were of equal clearness the one taken with the greater wind velocity was used, and no use was made of the other, although it was preserved in the records of the tests.

EXPOSURE OF THE MODELS.

The models were placed near the north edge of a large level field of the farm of the Purdue School of Agriculture. The nearest fence to the south or west was about 500 yards away. A quarter of a mile to the south is a railroad cut about 40 ft. deep and about 200 yards wide. At a distance of a quarter of a mile there were a few bushes, and the nearest trees were half a mile away. The country stretches off to the southwest and to the west in a level plane, broken only by the railway cut and a few small swales, until the nearest hill, about 50 yards high, is reached at a distance of about two miles. All the tests were taken with south and southwest winds, and for these winds the exposure seems as nearly perfect as it is possible to get in this part of the country. In a level plane of very great extent, it is probable that the diameter of the whorls of the wind would be much greater than here, and its structure, for limited areas, much more nearly uniform.

CONSTRUCTION OF THE MODELS.

Five members of the class of 1912 in the School of Civil Engineering of Purdue University, O. L. Canfield, D. C. Hayne, D. H. Miles, G. D. Miller, and C. W. Neu, selected the taking of these observations and reporting upon the same as a thesis assignment for

the B. S. degree. These men constructed the model shown on Plate III. The covering material was of plaster board, except for the additional base sections, which were made of 1½ in. planks to secure stiffness. The plaster board was used in order to make the models light and easy to turn in a direction normal to the wind, and to make the changes from one to another shape of model easy. The lack of stiffness of the plaster board made it difficult to handle, and in spite of very thorough painting, inside and out, its lack of durability added greatly to the difficulty of the last tests, so that some other material will certainly be used for further tests. The problem in the framing of the models was to construct them so as to facilitate the change from one shape to another, while a high wind was blowing. Two boxes were first made, 6 ft. x 10 ft. and 6 ft. x 5 ft., both 4 ft. high, and open top and bottom. Four gables were made for each different slope, and one peak strut for the 10 ft. and one for the 5 ft. house. The gables fitted into seats at each end of each box, and were latched in place. The ridges were socketed into the gables, and were also latched. Both the 5 ft. and the 10 ft. roofs were made in four pieces each. Two pieces, 30 in. wide, came down on either side from the ridge, and below them, on either side, were the pieces which varied with the different roof slopes. In the 10 ft. house an intermediate truss was found necessary to prevent the covering from bulging. To exclude the rain and to secure reasonable air tightness at that point, the peak was covered with thin sheet lead, which was readily shaped to fit in place, and whose weight prevented the lifting of the roof at the peak, during any wind which was tested. One small door was made at the end of each house. The 15 ft. house, for which tests are shown, was secured by putting the 5 ft. and the 10 ft. house together. When this was done an open gable was put in instead of the two closed gables which would come together, thus securing uniformity of pressure conditions throughout the inside. When the first trial readings were taken, the amount of the suction on the lee wall was so much smaller than the pressure on the windward wall, that we began to search for an error. We finally decided that the building not being air tight. having indeed some very considerable cracks, the escape of the air at the ends of the building was causing the inside pressure to be unduly low, thus diminishing the suction observed on the lee wall. If the ends and roof were absolutely air tight, and the openings in the windward and leeward sides were equal, the inside pressure should be a mean between the pressure and suction on the walls. The ends of a building whose side is normal to the wind receive suction over their entire area, so the suction area of any building is very much greater than its pressure area. This fact tends, obviously, to make the inside pressure less than the mean between wall pressures and suctions. While no attempt was made to make the models absolutely air tight, the large cracks were stuffed up, and

openings between the bottom of the building and the ground, due to slight inequalities of the ground, were filled with earth. The effect of this was to markedly increase the amount of the suctions. Openings were then made in both windward and leeward walls whose total area was 27 sq. in. The effect of these was to still further increase the suctions in comparison with the pressures. (See Plate IX.) The same plate also shows the effect of closing these openings on either side. Since our models were shorter in relation to their width and height than the ordinary building, it seemed best to approximate the conditions of a long closed building by leaving these openings in the walls, and thus secure more leakage through the walls than through the ends. No attempt was made to simulate the conditions of the buildings with louvres or open ventilator windows. A trial was made of the effect of opening the door in the end, during which the pressures were very greatly increased and the suctions nearly disappeared. The area of the door was about 15% of the area of one end. It is planned to make further tests under these conditions later.

CORRECTION OF DATA.

There were two sources of measurable errors, for which correction factors were computed and applied. The error due to the change in the scale was combined with the error due to variation in the *diameter* of the tubes and bottles. The factors are given in the table following.

The glass tubes used in these experiments were the ordinary glass tubes supplied to chemical laboratories, and these were found to have not only variation of diameter but *curvature* as well. These sources of error were partially removed by selection, and that due to curvature was finally computed for each tube and each reading thereof, and the corrections applied to the data. The method of computation was as follows: Assuming the curve of the tube to be a parabola, we call the error in rise in the tube above zero point X, the reading in inches R, and the curvature ordinate at the middle C. We have, then,

$$X = R^2C/116.6,$$

where 116.6 is the square of the half length of the tubes, 10.8 in. Since the total difference in level for 1 in. reading is, theoretically, 0.034 in., the percentage of error will be X/0.034 R, or,

$$\text{Error Factor} = R^2C/116.6 \times 0.034\,R = RC/116.6 \times 0.034.$$

For a reading of one-tenth on the scale, and a curvature ordinate of 0.01 in. at center, this gives 0.002.

For curvature ordinates of 0.02 in., 0.03 in., 0.04 in., 0.05 in., we have factors of 0.004, 0.006, 0.008, 0.010, respectively. For any tube, then, the proper factor multiplied by any number of tenths read, will give the correction to be applied to the diagram.

December, 1912

TABLE I.

CORRECTION FACTORS.

Tube No.	Curvature.	Diameter and Scale.
1	+0.0012N	1.42
2	+0.0022N	1.26
3	—0.0008N	1.35
4	—0.0028N	1.36
5	+0.0012N	1.26
6	—0.0018N	1.26
7	+0.0003N	1.29
8	+0.0024N	1.28
9	+0.0004N	1.29
10	+0.0020N	1.31
11	—0.0052N	1.23
12	+0.0050N	1.17
13	—0.0054N	1.26
14	+0.0020N	1.33
15	—0.0030N	1.29
16	+0.0024N	1.29

In the table above, the middle column gives the correction factor for curvature of the tubes. N is the number of tenths read on the scale. For small readings the value of these factors were all very small. The largest correction applied was about 3%.

The correction factors for the varying diameters and for the changed scale, were computed as follows:

$$L \times D_2^2 \times \pi/4 = H_1 \times D_1^2 \times \pi/4$$

where L is the length on scale for 1 lb. force, H_1 the drop of the liquid in the bottle for the reading L, and D_2 and D_1 the diameters of tube and bottle respectively.

Then $H_1 = LD_2^2/D_1^2$

And, since the difference in height for 1 lb. force is 0.202 in., and the tangent of the tube slope is 0.024,

$L \times 0.024 + LD_2^2/D_1^2 = 0.202$ in.

Solving for L and dividing 8 in. by the result, we have the correction formula

Factor $= 0.95 + 39.6D_2^2/D_1^2$.

From this formula the values in the third column of the table above were derived.

PRESSURE DIAGRAMS.

The corrected pressure readings were then laid out to a scale of 1 in. equals ½ lb. on the diagrams of the models on Plates IV, V, and VI. Pressures were shown on the diagrams outside the building and suctions inside. The corrected force observation is marked at the point at which it was laid out.

Lines were then drawn connecting the ends of the force ordinates, and, beyond, to the edges of the different surfaces. The areas

of the surfaces included by the different curves were then computed, giving the forces on a mid-section of each model 1 ft. in length. The total horizontal force on the 1 ft. section was then computed and noted below the diagram. Also the total horizontal and vertical forces on each roof were computed and noted above the diagram.

ACCURACY OF OBSERVATIONS.

The adjustment of the liquid to the zero point of the tube, which was accomplished by the addition or subtraction of liquid at the open end of the tube, was made within 0.01 lb. on the reading scale. This setting was found to endure from day to day when the apparatus was undisturbed, although moving the house and instrument often made it necessary to make new settings. The third hole in the bottle stoppers was opened after each series of observations, to check the return to zero. The percentage of error from error in setting to zero might be very large in the case of small readings, but it is to be noted that the effect on the pressure area determinations is quite small.

A rather indeterminate error, which is believed, however, to be of small amount, in the relative values, comes into the readings from the lag of the instrument. Due to skin friction, friction of flow in the tubes, and the length of air column over which air pressure is carried, the instrument requires an appreciable interval of time to register pressures. This time interval was approximated as follows: The wall tube was disconnected, the position of the liquid in the tube changed five divisions on the scale by blowing and by sucking at the wall end, and the time of return noted. At the end of five seconds the meniscus had returned to 0.15; at the end of ten seconds to 0.05; at the end of fifteen seconds to 0.02; and at the end of twenty seconds to 0.01. The remainder of the return occupied more than a minute. If moved a lesser distance, the return in the same time was, of course, closer, and for a larger movement, farther away. If it had been possible to close the third holes in all the bottles simultaneously, just as a gust was reaching its maximum intensity, a correction could have been figured for the reading of each tube, and applied to the diagrams. This, however, did not seem to be practicable in this instrument.

It appears quite certain that the error of registration of tubes moving different distances is not proportional, but, due to the care taken to obtain readings after the gust had reached its maximum, the observers are confident that the error from this cause is within 2% or 3%.

Another possibility of error comes into the pressure area determinations. It is obvious that between any two readings on the same surface the true pressure ordinates would have for their locus a smooth curve. There are many places, however, in which the curves might be laid out in a different manner from that used. At

the top of the windward wall, for example, the readings give no clue of the rounded corner of the pressure area shown. It is certain, however, that on roofs where the lowest reading is a large suction, this suction continues down to the edge of the roof and is probably, as shown, even larger at the edge. Now this suction is due to the velocity head of the air, and it follows that the upper horizontal laminae of the air in front of the wall have their pressure diminished by their nearness to this air current. It may be that the pressure passes through zero a little below the top of the wall, though the writer preferred the assumption illustrated. In a similar manner it was decided to curve the upper ends of the windward roof curve, when the leeward roof had forces of the opposite sign. Where the curves are irregular, as in some of the leeward walls, there is some chance for varying curves, but these variations of the curve give areas very little different from the ones shown.

It is to be noted that the lag error is almost entirely eliminated from the small readings, while on the other hand the percentage value of errors in area determinations will be smallest in the large readings.

Considering these various sources of error, the writer feels justified in claiming for the corrected force ordinates a relative accuracy such that they are within 3% of the truth, and for the pressure area determinations a final accuracy such that, when stated in terms of percentage of total horizontal force, they are not more than 2% away from the truth.

Since no use has been made of the absolute pressure amounts, although the observed data have been corrected to make them absolutely, as well as relatively, true, no discussion of accuracy in that respect is necessary.

TABLE II.

TABULATON OF PRESSURE AREA RELATIONS.

Length.	Height.	Pitch.	Total Horizontal.	Windward Wall, Per Cent of Total.	Leeward Wall, Per Cent of Total.	Roof Horizontal, Per Cent of Total.	Roof Vertical, Per Cent of Total. +Up.
5 ft.	4 ft.	1/5	1.30	49	36	15	21
		1/4	3.26	59	28	13	07
		1/3	3.03	51	22	28	—26
	5 ft.	1/5	2.13	71	26	03	39
		1/4	3.12	72	17	11	02
		1/3	3.69	68	14	18	—08
	6 ft.	1/5	3.26	80	19	01	24
		1/4	2.82	73	23	04	17
		1/3	3.40	70	21	09	11
		1/5	4.23	81	15	03	13

10 ft.	4 ft.	¼	3.61	67	24	09	21
		⅓	3.52	63	20	17	—06
	5 ft.	⅕	3.97	65	36	—01	61
		¼	3.12	63	37	00	40
		⅓	6.19	59	28	13	22
	6 ft.	⅕	7.77	88	17	—05	33
		¼	5.63	81	19	00	22
		⅓	8.93	60	29	11	03
15 ft.	4 ft.	⅕	4.30	73	20	07	37
		¼	3.85	65	17	18	10
		⅓	4.19	60	15	25	02
	5 ft.	⅕	3.76	59	38	03	39
		¼	5.78	64	30	06	19
		⅓	8.12	56	28	16	07
	6 ft.	⅕	3.14	77	25	—02	36
		¼	4.04	60	34	06	27
		⅓	6.99	52	39	09	26

COMPARISON OF DATA.

Table II shows the effect on each portion of the surface in terms of percentage of total horizontal force on the building.

Table III shows the total vertical effect on the roof, in terms of

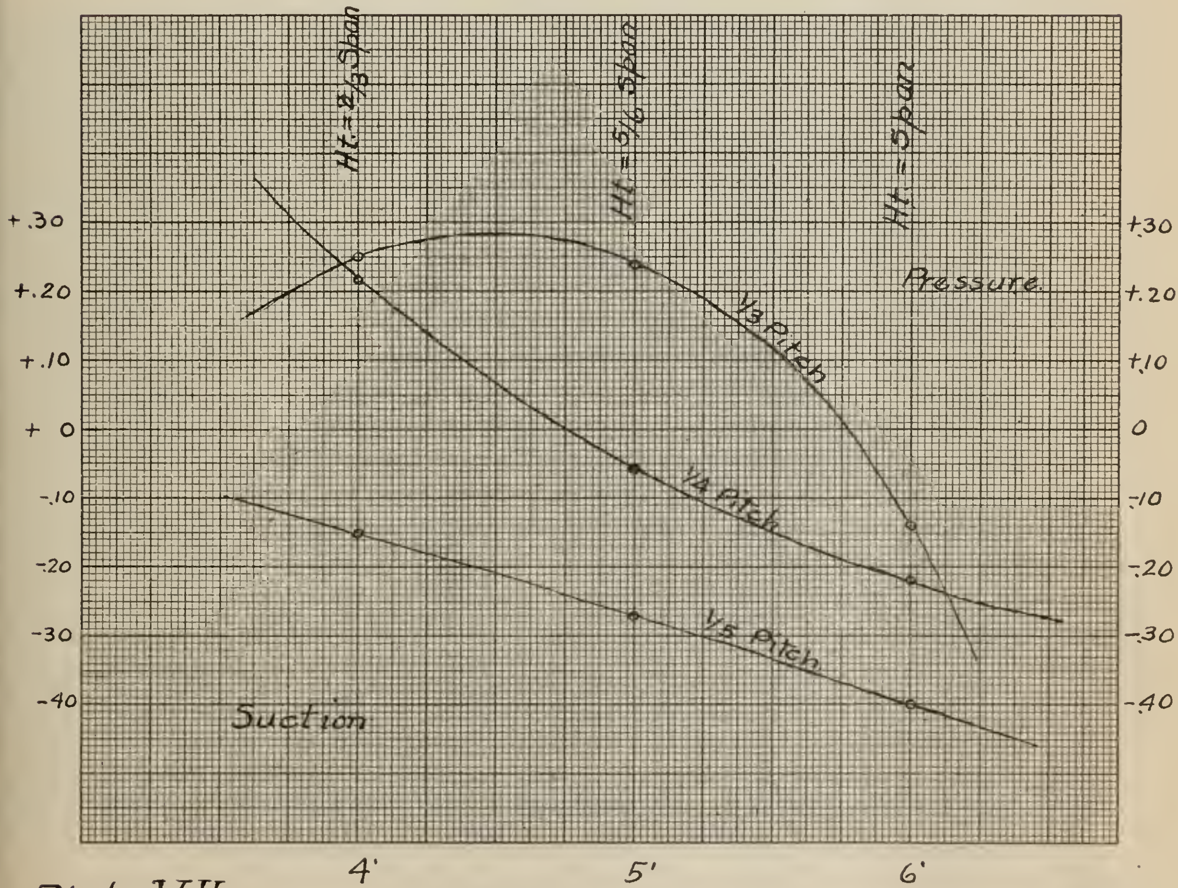


Plate VII

Model 15' Long.

Amount of Force on Windward Roof in Terms of Per Cent of Unit Pressure on Both Walls.

percentage of total horizontal force on the building. It is especially interesting to note that this may be, for some shapes, as much as 61% of the total horizontal force.

Table IV gives the total force on leeward wall in terms of percentage of total force on both walls. Both in this table and in Table III, the three vertical columns under each pitch are for the 5, 10, and 15 ft. lengths of building, respectively.

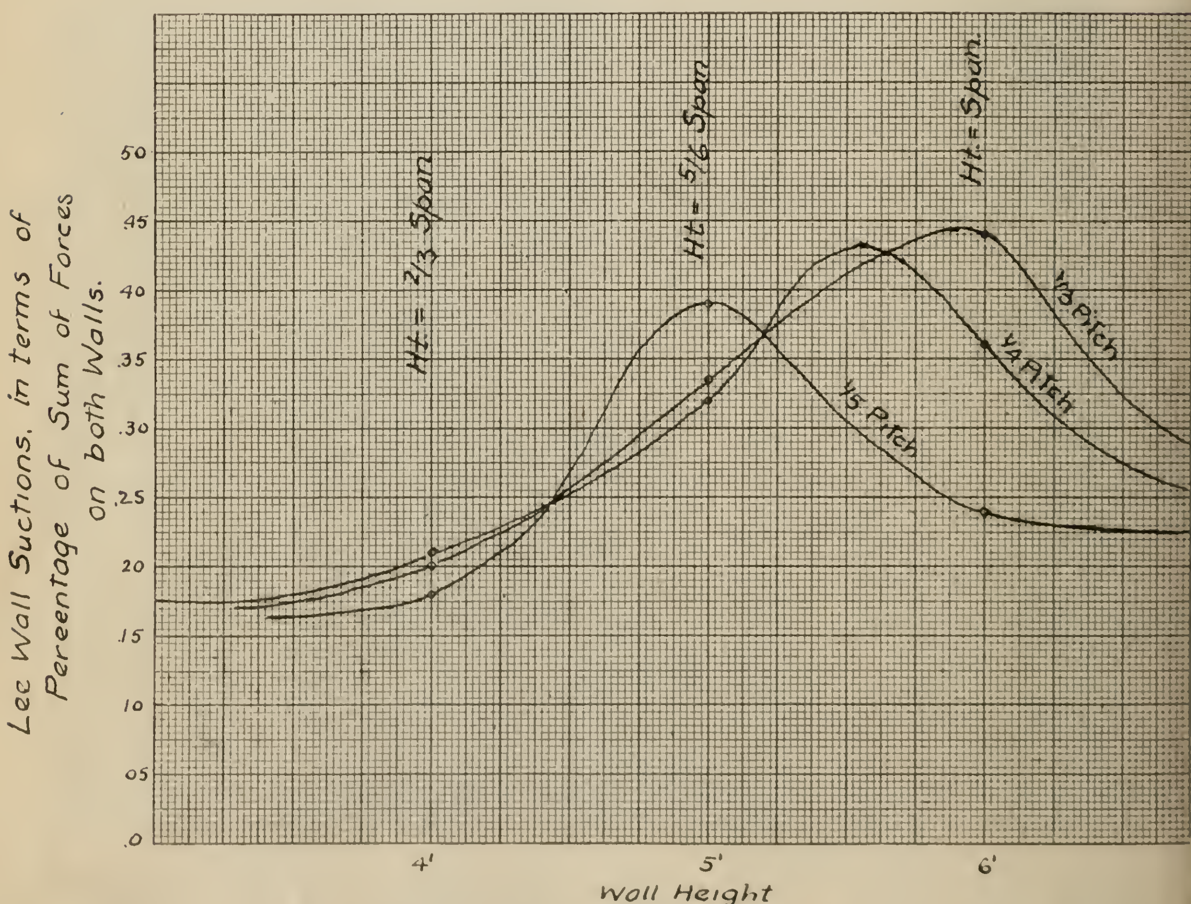
Windward Roof.—The ratio of unit pressures on the windward roof to the sum of the unit pressures on both walls was computed for the 15 ft. model. The result is shown graphically in Plate VII.

TABLE III.

VERTICAL UPLIFT IN PERCENTAGE OF TOTAL HORIZONTAL FORCE.

Wall Height.	1/5 Pitch.			1/4 Pitch.			1/3 Pitch.		
4 ft.	21	13	37	7	21	10	—26	—8	2
5 ft.	39	61	39	2	40	19	—8	22	7
6 ft.	24	34	36	17	22	27	11	3	26

From the table above, the average of the 1/5 pitch figures is 30%, of the 1/4 pitch, 17%, and of the 1/3 pitch, 03%.



Variation of Lee Wall Suction - 15' House.
Plate VIII

Increases of height and length both tend to increase the amount of the vertical force.

TABLE IV.

FORCE ON LEE WALL IN PERCENTAGE OF TOTAL FORCE ON WALLS.

Wall Height.	1/5 Pitch.			1/4 Pitch.			1/3 Pitch.		
4 ft.	42	16	18	32	26	21	30	24	20
5 ft.	27	36	39	19	37	32	17	32	33
6 ft.	19	16	24	24	19	36	23	32	44

Plate VIII shows graphically the change in lee wall percentages for different heights of wall for the three pitches. Only the 15 ft. model observations were used in this plate. The curves for the 10 ft. length resemble these, although the points of maximum percentage are moved to the left, and are in the same order as to pitch. In the 5 ft. length of model the curves do not agree with each other so well, or resemble so closely the curves of the 15 ft. model observations. The shape of these curves is given them arbitrarily, as the three points given by the observations do not completely locate them. There are some general conclusions which the pressure diagrams enable one to draw, and which guided the writer in making these curves.

(a) The increase of height of wall tends to decrease relatively the average amount of pressure on the windward wall. The decrease of wall height, while the roof height remains unchanged, tends to produce pressure on the windward roof. The pressures then do not pass through zero at the top of the wall, but at a point some distance up the roof, and the average on the wall is increased.

(b) The increase of height tends to increase relatively the average amount of suction on the leeward wall. The direction of the filaments, as the air leaves the leeward slope, is evidently an important factor in determining the suction on the leeward wall. The more nearly horizontal the direction of these, the greater will be the leeward wall suction. But the longer the roof, in relation to the height, the more nearly will the air filaments at the leeward eave be brought parallel to it. Turning these filaments into a direction parallel to the surface of the ground, develops a higher absolute pressure and therefore a lower suction, than when the filaments are more nearly horizontal. Where, then, the roof is long in comparison with the height, or, the span being constant, where the height is small in comparison with the span, the leeward suctions will be relatively small.

(c) The relative amount of the air flowing around the end of the building increases as the height increases. When the building is short in comparison with its height, the flow of air around its ends has more influence upon the relative amounts of the pressures and suctions than the flow over the top. On a thin plate exposed in an air current, the maximum pressure is found on the

windward side midway between two edges around which free flow takes place, and the minimum suction will be found on the leeward side directly opposite the same spot or line. As the amount of the end flow increases, the tendency of the leeward suction at the middle section to become a minimum, as also the tendency of the windward pressures to become a maximum, increases.

The effect of (a) is probably not very large. But from (b) we have the relative amounts of the leeward suctions steadily increasing as the height increases. The limit of the ratio will be the ratio of lee suctions on a very long thin plate with one edge resting on the surface of the ground. We have no test data on this case, but these tests seem to indicate that this limit is very nearly 50%. As the height increases, however, the influence of the end flow on pressures and suctions at a middle section steadily increases, finally overcoming the tendency of the lee pressures to increase, and actually causing them to diminish. They will then continue to diminish until, the confined edge of the building becoming very small in comparison with its height, it approaches as a limit the ratio of suction for a long rectangular plate in air, which, as shown by Stanton, is about 35%. In the smaller pitches of roofs the maximum percentage of the leeward wall suctions will be arrived at more rapidly, throwing the points of maximum curve ordinates on Plate VIII to the *left,* for low pitches.

CONCLUSION.

In view of these results, the ordinary methods of assuming wind loads on mill buildings ought to be somewhat revised. For the case of roof trusses on masonry walls, or on steel bents with long diagonals, a suction effect in the neighborhood of 0.4 of the unit wind pressure should be placed on the leeward roof of all closed buildings, and a pressure or suction derived from the curves drawn from the observations, placed on the windward roof. The resulting stresses will not only be different in amount from those computed on the present basis, but will in many members, differ as to sign. Wind loads on purlins might in most cases be entirely omitted, and where considered they might be made much less than at present. The necessity for secure anchorage, not only to prevent sliding, but to prevent actual uplift, is strongly confirmed by these tests.

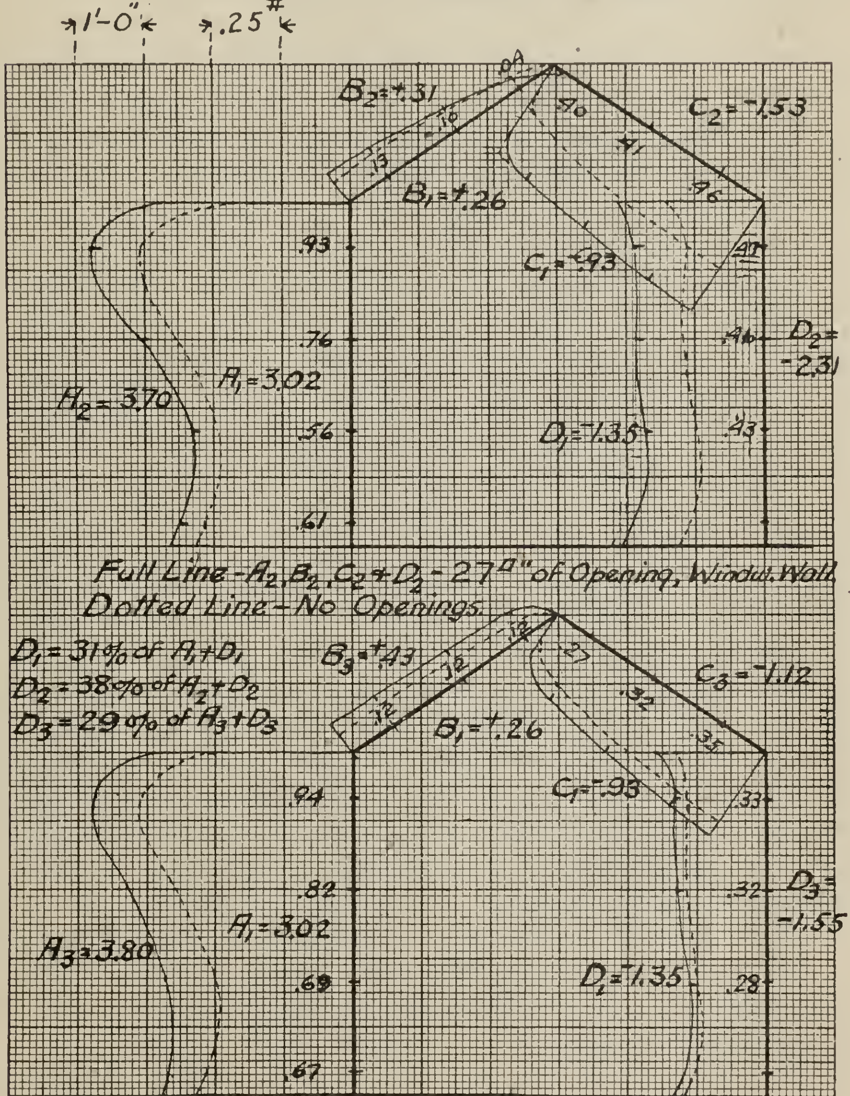
In buildings with knee-braced bents, in addition to the preceding points, the suctions on the leeward wall should be considered. Approximate curves might be made for each pitch and for each height ratio, and the leeward wall unit derived therefrom in any given case. This, beside being troublesome to the computer, still leaves his results inaccurate, since if the pressures on the two walls be unequal the points of contraflexure will be actually at different heights, though in view of the labor otherwise involved, he must consider them to be at the same height.

Where there is an opening as great as 2% or 3% of the outside surface, the suctions will be seriously reduced or augmented, according to which side the openings are on. If on both sides, the

PLATE IX

Effect of Openings in Walls.

15' Length, 5' Height - 1/3 Pitch.



Full Line-A3,B3,C3+D3-27□"of Opening, Lee Wall.
Dotted Line-No Openings.

pressures and suctions will not be seriously affected, except locally, unless the openings are very much greater than this.

It is intended to endeavor to get some information on the effect of ventilator openings in some further tests, as well as to test the

pressures on curved roofs as constructed in train sheds and drill halls.

The writer wishes due credit to be given Messrs. Canfield, Hayne, Miles, Miller, and Neu, for the effort and care which they devoted to the taking of these observations, often in severe weather.

DISCUSSION.

Professor Smith: I want to call attention to one thing that I am sorry was not included in the paper, and that is the fact that the apparatus which I believed to be novel when it was laid out and used, and when the paper was written, I have since found is quite old. An exactly similar apparatus was installed in Eads Hall in Washington University by Professor Nipher and has been there since 1907. What use has been made of it I do not know, because the results of his observations have not been reported in any engineering papers. I have not yet found in general scientific literature the results of his tests. I am quite sure, however, that there have been no tests upon models of different shapes by that apparatus. I think that it has remained in Eads Hall since its installation, so that the effects of variations of shape, so far as I have been able to find, have not been studied before.

I especially desire to get suggestions in regard to what will be the most valuable phase to take up after this. We plan to start work again this year, and make further tests to determine, if possible, the distribution of pressure on curved roofs, as train sheds and drill halls and similar buildings where one, two, and three hinged arches of large span are carrying the roof. It is probably true that mill buildings have been built without much regard to the wind and have stood up, and some of us build them with what I believe to be a wrong assumption as to the direction and amount of the pressures and without a resulting failure; but with very large structures, such as the largest of our train sheds, it is important to know just what the loads are. I shall be much interested to have any suggestions in regard to the exposure. We think of having both ends closed, one end open, and both ends open, and to duplicate those tests with an opening at the top for ventilation.

Mr. Baker: What do the figures below the diagrams in Plates IV, V, and VI, under the small arrows, represent; the intensity of the wind?

Professor Smith: Those figures represent the total horizontal force—including the horizontal component of the roof forces. The sum of *A* and *D*, for instance, on Plate IV, on the 6 ft. height, one-fifth, *A* is 2.6, *D* is 0.63; the total would be 3.23, and the sum of the horizontal components *B* and *C* makes this 3.26.

President Armstrong: What are the relative lengths of these

models, compared to the height and width upon any length of model?

Professor Smith: All the observations were taken at the mid-section of the buildings. In the 5 ft. house they were taken 2 ft. 6 in. from the end, and the houses on Plate IV are all 5 ft. long, and the span of all the houses, all the twenty-seven models, was 6 ft. That is not noted on the diagram, because it was a constant. The heights vary as shown in the figures immediately under the model, as—four, five or six ft., and with one-fifth, one-fourth, or one-third pitch of roof.

S. T. Smetters, M. W. S. E.: I would ask Professor Smith if his apparatus could be applied to a building like this, by arranging some of the window openings so that the pressure could be taken at, say, a window on the west side, one on the north end, and one on the east side near the corner, and taking readings simultaneously, with the three different apparatus. Also, take one, say, at the twelfth floor and another at the fourteenth or sixteenth floor at the north end of this building, and see whether there would be "a hole in the air" out on the corner of Jackson and Dearborn Streets. Some of the aviation men have found that we have an air hole over Lake Michigan about opposite Twelfth Street. Can the tendency of the air currents to move in a certain direction after getting away from the buildings, be determined?

Professor Smith: Undoubtedly tests on office buildings showing the exact amount of the wind loadings thereon would be interesting, although the subject did not seem to be quite so acute as the case of mill buildings or of power houses and train sheds. It is probable that very interesting results could be had in testing out a twenty story building to ascertain just how much variation there really is in the wind pressure at the various heights of the building due to the various shapes. Whether we could locate any "air hole" or not, I do not know. I doubt whether we would be justified in reducing wind loads on the buildings if we did locate it.

President Armstrong: Would it not be possible to verify some of the results of these experiments, especially with reference to the effect of suction, by extensometer tests on trusses? Has it ever been tried?

Professor Smith: I think it might be done. It is quite hard to separate out the stresses which are caused. I experimented with an extensometer on a column carrying a crane load, passing the crane back and forth, and obtained rather interesting results. The action of a roof truss is quite apt to be not perfectly simple. Of course, if one can get his apparatus up at the right time to get a sixty mile wind, he might overcome the tendency to a little arch action, perhaps, or some other tendency toward inde-

terminate stress and really get corroborative results. It is rather difficult and I imagine that is the reason that every one has boggled at it.

Prof. H. P. Boardman, M. W. S. E.: The experiments described in the paper are very interesting, and show that the problem of pressure and suction effects on roofs and walls of buildings is much more complicated than was formerly supposed.

The method used to measure the pressure and suction, and photograph the effect in the inclined tubes for all exposures at once, was very ingenious, but does it follow that the pressure or suction so indicated is just the same as that acting normally on the corresponding building surfaces? Can this be equally true of the results from tubes connected with the four different faces of the same building?

I think Prof. Nipher, of Washington University, St. Louis, has shown that a tube inclined towards a moving current of air at an angle of 60° with it, transmits zero pressure effect, i. e., neither pressure nor suction; that at an angle of 90°, or any other angle greater than 60°, the effect is negative, or a suction while at an angle less than 60° pressure was transmitted by the tube.

The tubes at the different exposures of the model buildings made angles varying from 0° to 180° with the general direction of the wind, but does it necessarily follow that the tubes set normally to the building surfaces transmit the same pressure that is acting on those surfaces? I think that is a point that should have experimental verification before acceptance, especially for the inclined-roof surfaces.

I did not notice in the paper any statement of an attempt to determine the wind velocities coincident with the pressure tests. Neither did I see an explanation of the significance of the number accompanied by an arrow pointing to the right placed under each figure of Plate VI. I concluded they were the records of the pressure board placed near the model building and indicating pounds per square foot pressure.

H. G. Tyrrell, M. W. S. E.: It may not be generally known that elaborate experiments were made in England by Stephenson. to determine the relative pressure of wind on surfaces at different elevations above the ground. These experiments were made on small areas at heights of 5, 10, 15, 25 and 50 feet, and the results are as given in the following table:

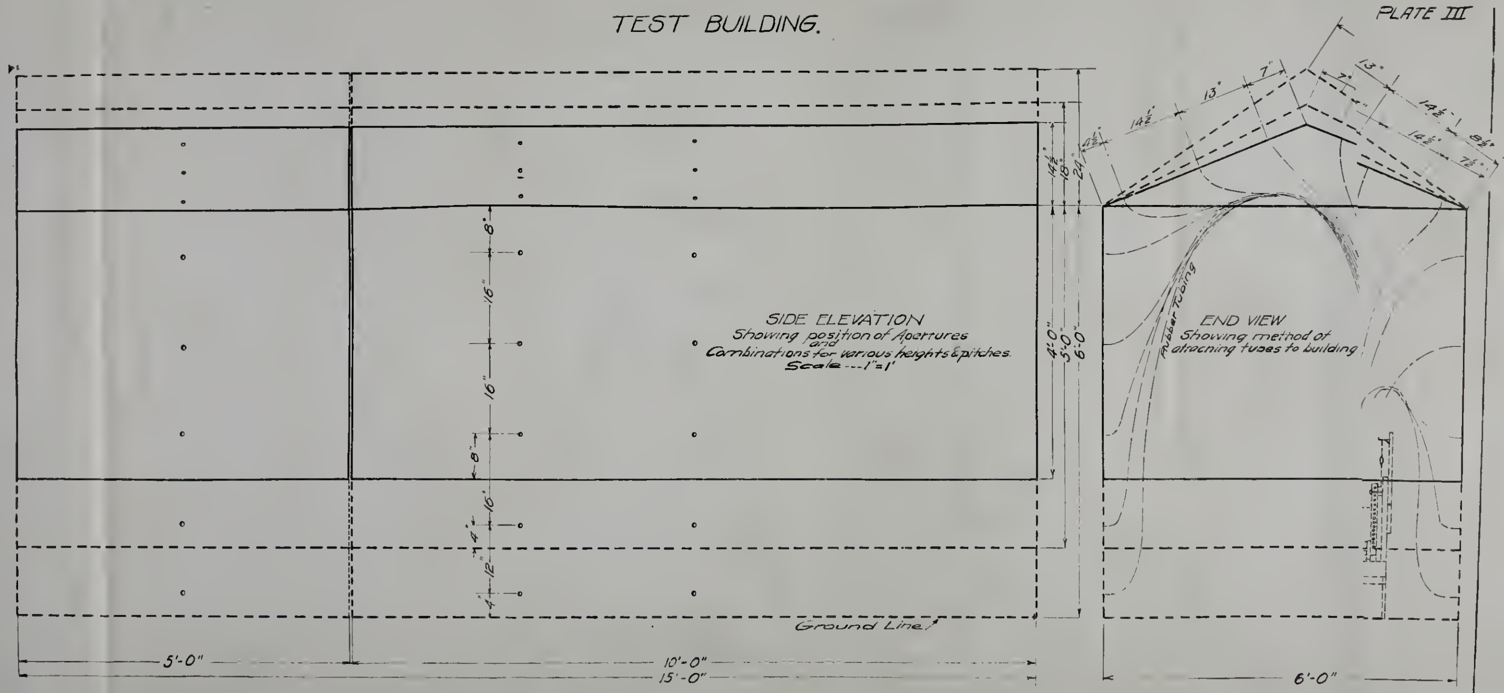


PLATE III
TEST BUILDING.
SIDE ELEVATION
Showing position of Apertures and Combinations for various heights & pitches.
Scale ---1"=1'
END VIEW
Showing method of attaching tubes to building
Rubber Tubing
Ground Line
5'-0"
10'-0"
15'-0"
6'-0"
4'-0"
5'-0"
6'-0"
8"
16"
16"
8"
16"
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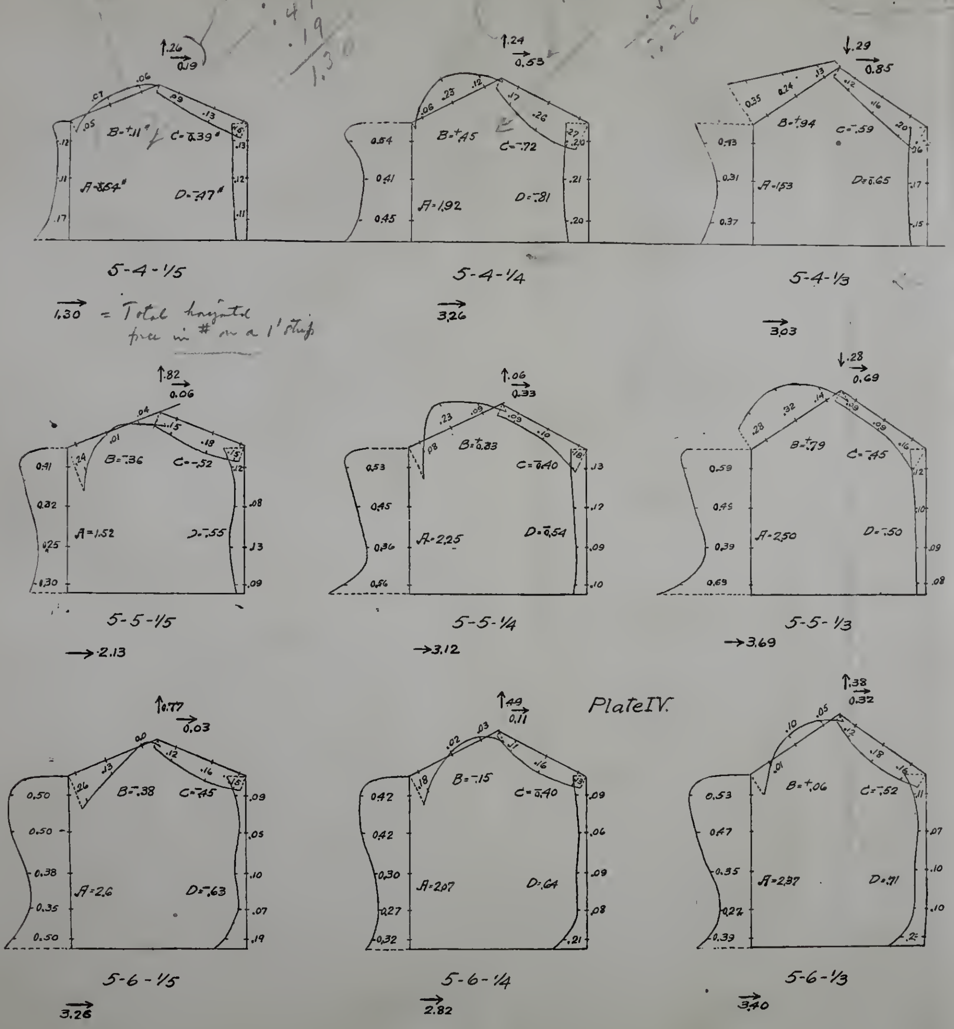
Inside pressure = atmospheric approx. p. 994

Roof span = 6'



See Table 2

(see p. 990, top)

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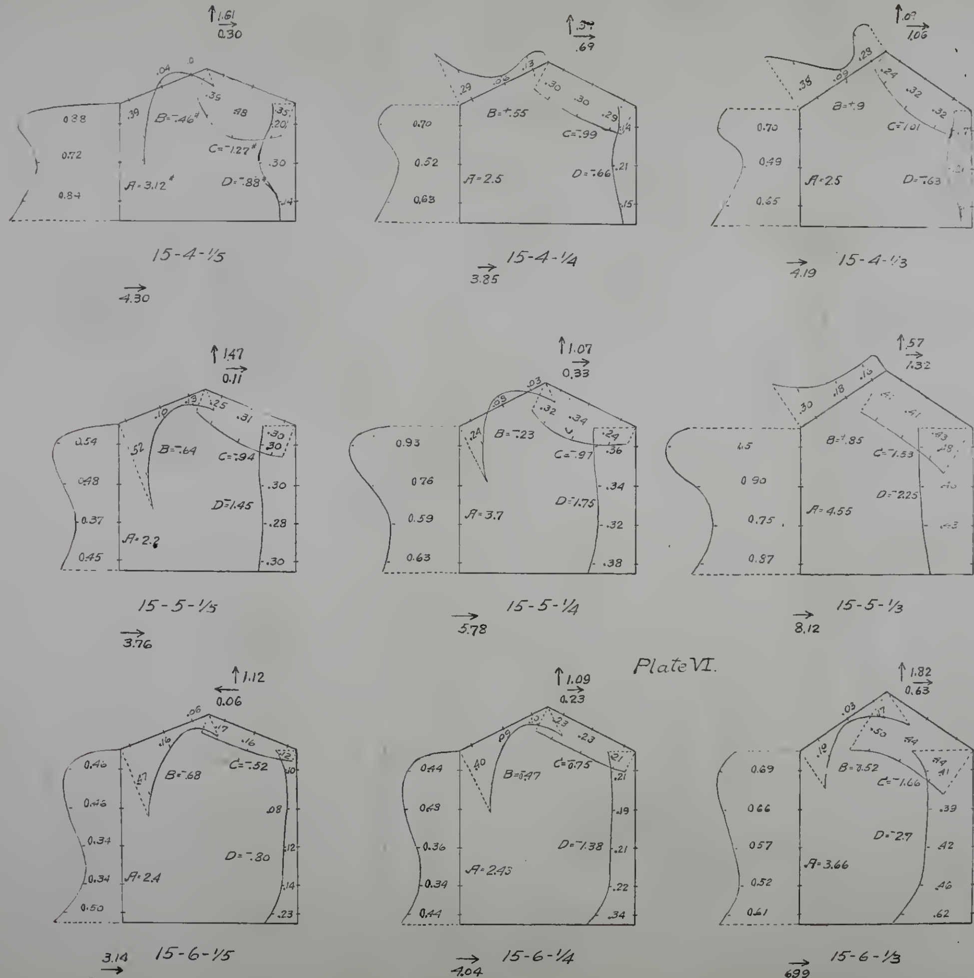
15-4-1/5
15-4-1/4
15-4-1/3
15-5-1/5
15-5-1/4
15-5-1/3
Plate VI.
15-6-1/5
15-6-1/4
15-6-1/3

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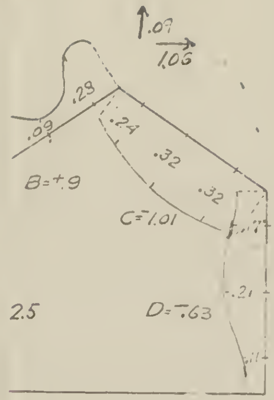
Smith—Wind Pressure on Buildings

Plate VI



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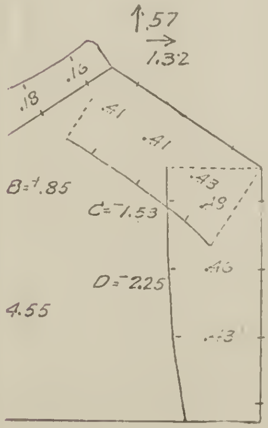

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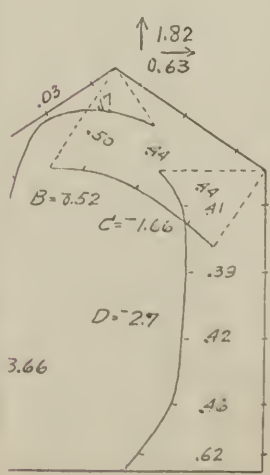


15-6-1/3

Stephenson's Experiments for Wind Pressure.

	HEIGHT ABOVE GROUND IN FEET.				
	5	10	15	25	50
	4	6	6	6.5	7.5
	7	17	18	21	23
	13	23	25	30	32
	19	28	31	35	40
	26	32	34	37	43
Average	13.8	21.2	22.8	25.9	29.1

These results show relative proportions only on comparatively small surfaces, but they prove conclusively that the effect of wind increases with the height, and high above ground is usually twice as great as near the earth. In urban districts buildings often shelter each other to such an extent that it is frequently safe to entirely disregard wind up to a height of 20 to 30 feet. On large walls, there is a tendency towards uniformity of pressure at varying heights, owing to the elasticity of the air, the conditions being different to those in Mr. Stephenson's experiments, which were on small areas. On the interior of buildings, wind pressure may be serious where the sides are open or broken with many doors or windows through which air currents may enter. When open enough to admit free air, wind pressure on the two sides may be nearly equal, and the sum of the two sides will be the area exposed to pressure. The ends of high single-story buildings, such as erection shops for metal works, are often more difficult to brace than are the sides, for they lack the means of bracing at the level of the lower cord. Conditions evidently vary for different buildings, and each one should be proportioned according to its need.

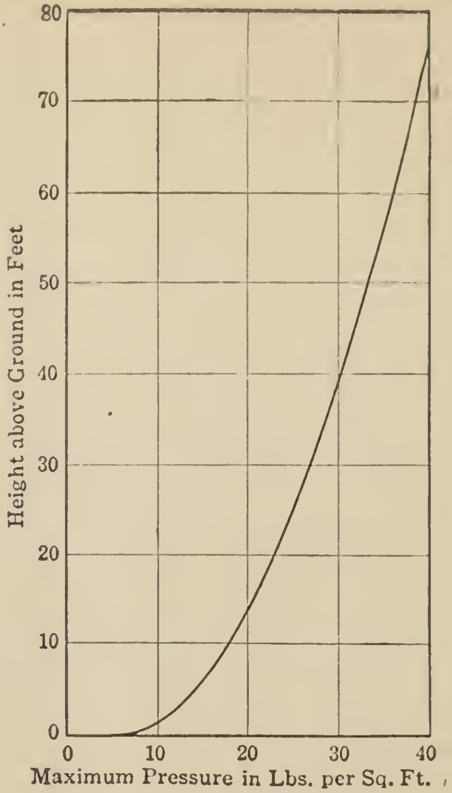
From the above investigations, it appears that it is usually sufficient, at a height of 80 ft. or more above ground, to provide for a wind pressure of 40 lb. per sq. ft., and for less heights, to reduce this amount according to the formula

$$P = 4\sqrt{H} + 5$$

where P is the wind pressure in pounds per square foot, and
H is the height in feet to the area in question.

These results are shown by the following diagram,* and it will be seen that they conform closely with Mr. Stephenson's experiments:

*From Tyrrell's *Engineering of Shops and Factories* (page 46).



As a pressure of 30 lb. per sq. ft. corresponds with a velocity of 70 to 80 miles per hour, and can occur only from violent storms or hurricanes in exposed places, a greater amount need rarely be assumed.

CLOSURE.

Professor Smith: The speaker is quite sure that the indications of the tubes can be relied upon. Being normal to the surface, they must receive any normal action of the wind on the roof or wall, to a degree equal the intensity of its action on the building surface.

Professor Boardman seems to me to be in error in assuming that the pressure or suction on a building surface is caused by direct impingement of the air laminae. As a matter of fact, the greater part of the building is surrounded by air that is practically still. This can be verified by allowing a cloud of smoke to blow over the building, and observing its path.

Professor Nipher's experiments are not familiar to me, but I suppose they were carried on with a tube alone projected into the air current. When the tube was turned, its open end assumed, in various stages; the successive positions of the surfaces of the buildings tested by the writer, and from what Professor Boardman says, must have shown similar effects.

Professor Boardman is correct in identifying the figures of the upper scale in the apparatus.

As to velocity determinations, it was hoped to find them from the pressure board readings. The use of an anemometer in front of the building was omitted on account of the possible disturbance of the structure of the air. Since the relative intensities of wind effect at different points was the whole object of these tests, the actual velocities are not essential to their completeness.

Mr. Tyrrell has raised a very interesting question. It has often been advanced that since the velocity of the air is less near the ground than at a considerable height, we might reduce the amount of the wind units as we approach the ground.

These tests seem to show that while the pressures and suctions do vary up and down the walls, they do not vary in a manner at all resembling the curve shown by Mr. Tyrrell. Probably there is a somewhat greater pressure on high buildings than on low ones when exposed to the same wind. Tall, narrow buildings, which will allow the greater part of the detained air to escape around the sides instead of going over the top, will have their pressures strongly affected by the curve shown by Mr. Tyrrell. The intensity of the pressure at any point will depend largely upon the velocity of the wind in that horizontal stratum. But buildings long in relation to their height will have practically uniform pressure over their sides, and those pressures will be very largely governed by the velocity of the wind at the highest point in the building.

December, 1912

NEW METHODS OF APPROACHING THE SMOKE PROBLEM

Osborn Monnett.

Presented November 4, 1912.

POLICY.

In taking up this question it might be well to outline briefly the policy of the Chicago Smoke Department in its dealings with the public. In a word, the Department has adopted a policy of educating the public in the methods of preventing smoke; plant owners, engineer and firemen are shown the proper method of constructing furnaces for various kinds of service and are also instructed in the best manner of handling the equipment they have. For this educational work the Department has a number of engineers whose duty it is to work with the owners and operators of plants, investigating and advising means, which from experience of the Department teaches them to be best under the circumstances.

The problem in each plant is carefully investigated and thoroughly considered by the engineers, after which recommendations and suggestions are made to the owner as to the method of handling his plant or as to the reconstruction work necessary in order to operate within the Smoke Ordinance.

Sometimes entire boiler plants are rebuilt in order to stop smoke, and very often furnaces are reconstructed throughout. It sometimes happens that after a new plant is put in operation it smokes, and the operating crew finds it difficult to run without making objectionable smoke. The Department gives such a plant special attention and stays on the job until the cause of the trouble is definitely known and changes have been made that will rectify matters.

CONSTRUCTION WORK CAREFULLY SUPERVISED.

There are a great many good furnaces on the market today. The problem is to have the furnace and the boiler arrangements such as to give the best results. There are no certain makes or styles of furnaces that cover every case; in fact, the largest number of furnaces installed in the city since the organization of the present Smoke Department, have been designed especially for the plant in which they are used.

It is the aim of the Department to get automatic stokers in all plants that are large enough to warrant the expenditure. As long as furnaces are hand-fired there will be trouble in keeping the smoke

down, because so much depends upon the personal element. There are, of course, exceptions to this rule of requiring mechanical stokers, a recent case being where three large water-tube boilers are to be installed in a building where large quantities of wood refuse will be burned. Here it is thought advisable to install a good hand-fired, wood-burning furnace, and there is no question but what such a furnace, properly designed, will run easily within the Smoke Ordinance as interpreted today.

As regards mechanical stokers, it has been the experience of the Department that practically every stoker on the market today can be applied under circumstances which will allow it to run satisfactorily from the smoke standpoint; however, it is a study to know whether a plant is surrounded by all the proper safeguards and to be certain of the results that will be had when the furnaces are put in operation. There is no standard set of conditions which will meet every case. It is the aim of the Department to get all plants to go in under the best engineering conditions possible; a plant in the first place should be correctly designed and built with due consideration given to all requirements for smokeless operation, and then it should be properly operated. *Proper operation is the most important thing of all and in many cases the most difficult thing to obtain.*

SEMI-BITUMINOUS COAL A MAKESHIFT.

If an existing plant cannot run within the Ordinance, and the necessary changes to fit it so as to run within the Ordinance are practically out of the question, then the Department can and does recommend a coal of less volatile content than the grade ordinarily used, but this is taken more or less as a makeshift from the fact that semi-bituminous coal frequently disappears from the Chicago market due to weather conditions, obstructed railway traffic, or to labor troubles, and this recommendation is made only to tide the plant over until such time as it can be rebuilt.

CLOSE STUDY BEFORE RECOMMENDATIONS.

A plant that violates the Smoke Ordinance at frequent intervals is given special attention by the engineers of the Department. These engineers visit the plant and study the conditions as found while under operation. After a thorough investigation of conditions, such as the fluctuation of load, and draft conditions, which would include breeching area, size of stack, gas passages through the boilers, etc., together with character of fuel, construction of furnace, and any other item which has any bearing whatever upon the operation of the plant tending to produce or prevent smoke has been taken into consideration, recommendations are made as to the best course to pursue in order to eliminate smoke.

In plants where considerable reconstruction is necessary, these visits oftentimes cover a period of several weeks, and in some cases even months, before the engineer is thoroughly familiar with all the difficulties to be met in the plant, and is in a position to make recommendations which, if followed, will necessitate the expenditure of considerable money.

Owners and chief engineers of these plants sometimes think that the Department's recommendations are far more sweeping than are necessary for the results sought, and in cases of this kind it is necessary to work with them and devise a scheme whereby such work as they do will be a benefit and a part of a general scheme of improvement to be executed step by step.

EXAMPLES OF PROCEDURE.

The following is a case of this kind: The plant has nine large water-tube boilers that were upon one stack. The Department's recommendations were to take four boilers off the stack and change all furnaces from vertical baffle to horizontal and draw all stokers out 18 in. in order to get proper proportions in the furnace. In this particular case the consulting engineer for the company did not think that work of as extensive a nature was necessary. It was therefore decided that they would build one stack 175 ft. high and large enough to take care of the two boilers farthest from the original stack. Later, as developments had proved that the stack was needed, a second stack was built also 175 ft. high, and large enough to take care of the next two boilers farthest from the original stack. Developments are now proving that it will be necessary to change the furnaces throughout the entire plant, and this work will probably be done in a short time. From the first investigation to the completion of alterations will probably cover a period of more than three years, and the cost to the plant owners will be something over $20,000. But besides the benefit of clean chimneys, the efficiency will be higher, and the capacity of the boiler house will be materially increased with no increase in the number of boilers.

In another plant there were eight chain-grate stokers under water-tube boilers, vertically baffled. Shavings were being burned on most of these grates and coal on some of them. The plant has been changed. Six of the chain grates have been taken out and Dutch-oven furnaces with three-span deflection arches have been installed. The entire system of handling shavings has been altered. This work occupied a period of about 1½ years after it was decided definitely what could be done, as it was absolutely necessary for the plant to be kept in operation at all times, and it was not known positively at first what was the best design of furnace for the particular plant as the problems presented were unusual. Now it is possible to operate this plant day after day without any dense

smoke, where previously it made the blackest smoke every minute of every hour day and night.

There are hundreds of instances where the same procedure has been followed, but these two are mentioned as examples of the method used of meeting the difficulties. As a general rule the Smoke Department first finds out what is necessary to be done in a plant, in order that it may be operated without violating the Smoke Ordinance, and an effort is then made to get the owners to do the work that will give the results sought. If it is impossible to get sufficient co-operation from the owners so that they will work out a solution of the smoke problem in their particular instance, resort is made to the court for prosecution on evidence of violations by their chimneys. When, in the judgment of the Department, a consistent effort is made to better conditions, prosecutions for violations are not instituted as the purpose of the Smoke Department is to eliminate smoke and not collect fines.

ENGINEERING ADVICE.

The Department has been subjected to considerable criticism in the past for its activity in undertaking to advise people in trouble with regard to reconstruction work. In this connection, however, it must be borne in mind that the purpose of the Department is to suppress smoke; that the public is looking to the Department to relieve it of the unnecessary air pollution caused by smoking chimneys, and that the Department must of necessity get action; otherwise it has no excuse for existing. To illustrate this point, a recent case may be cited in which an old-type chain-grate setting, vertically baffled, was giving a great deal of smoke trouble. A reputable consulting engineer approached the company with a proposition to put the plant on its feet, both from the efficiency and smoke standpoint, but the proposition was rejected although the company was at the same time professing to the Smoke Department that it was willing to do anything within reason to stop the plant smoking. Finally, after coming into court a few times, the management instructed the chief engineer to hire a bricklayer for $2.00 per day, who would be willing to work 10 hours per day, and a bricklayer's helper at $1.50 per day for 12 hours. With this force, work was started on the reconstruction of the furnaces. After obtaining some hundreds of dollars worth of consulting engineering from the Smoke Department and having the work supervised by the Department and stoker manufacturer, the plant was satisfactorily cleaned up. But the case illustrates the backwardness with which some proprietors attack the problem, and the reluctance with which they spend any money in trying to solve their difficulties. If the Department would allow this class of steam user to follow his own inclination, the City of Chicago would never solve its smoke prob-

lem, as it is really the reconstruction jobs which are cleaning up the city.

SPECIAL RINGELMANN READINGS.

Early in the spring of 1912 the Department had a great many Ringelmann chart readings taken on different classes of industries. It was realized at this time that the Smoke Ordinance as interpreted was not elastic enough to take in all classes of offenders, and that some method was needed in order to bring all classes to a realization that improvements were to be desired. This can be illustrated by reference to the provision of the Ordinance which says that only dense smoke is a violation. Dense smoke, according to the Ringelmann method of reading, is No. 3 smoke or worse (Fig. 1). If a plant makes a continuous No. 2 smoke, the total amount of smoke made in a 10-hour run would be enormous, yet the plant would easily run within the Smoke Ordinance and the matter could not be taken into court.

The smoke density of a plant running a continuous No. 2 smoke on the Ringelmann chart would be 40%, yet another stack might violate the Smoke Ordinance in seven minutes of continuous dense smoke, and be absolutely clear for the rest of the hour or the rest of the day, and the smoke density for the day would not figure more than 2% or 3%, yet the second offender would be liable to prosecution while the first offender, who was really making the most smoke, would go entirely free. It was with this thought in mind that a system of Ringelmann chart observations was instituted during the past summer to ascertain whether the plants that were making the smoke, were actually violating the ordinance.

CALCULATIONS FOR SMOKE DENSITY.

According to the technical interpretation, the Ringelmann chart reading, a copy of which is shown in Plate I, consists in reading the smoke density of a stack every 15 seconds for the period under observation; in this way we get a very close record of the behavior of the stack. In the case of Plate I, observations commenced at 11:00 A. M., and ended at 2:50 P. M., with an hour for lunch. The method of figuring the data on a chart of this kind is as follows: The number of observations of Nos. 1, 2, 3, 4 and 5 smoke are tabulated and reduced to smoke units as follows:

70 units of No. 1 smoke =	70
34 units of No. 2 smoke =	68
100 units of No. 3 smoke =	300
29 units of No. 4 smoke =	116
146 units of No. 5 smoke =	730
Total	1,284

As the readings were taken every 15 seconds, this figure 1,284

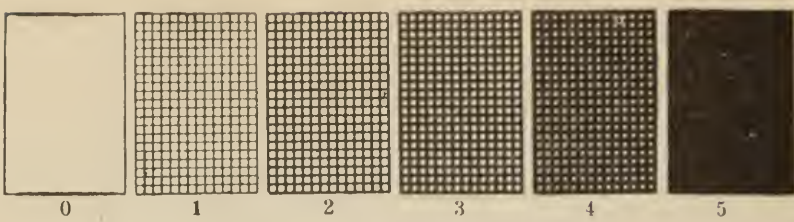


Fig. 1. Ringelmann Chart.

divided by 4 gives the smoke units for the period under observation, and as one smoke unit represents 20% density, the calculation for density would be $\dfrac{321 \times .20 \times 100}{170} = 37.7.$

The Ringelmann chart reading shows not only the per cent

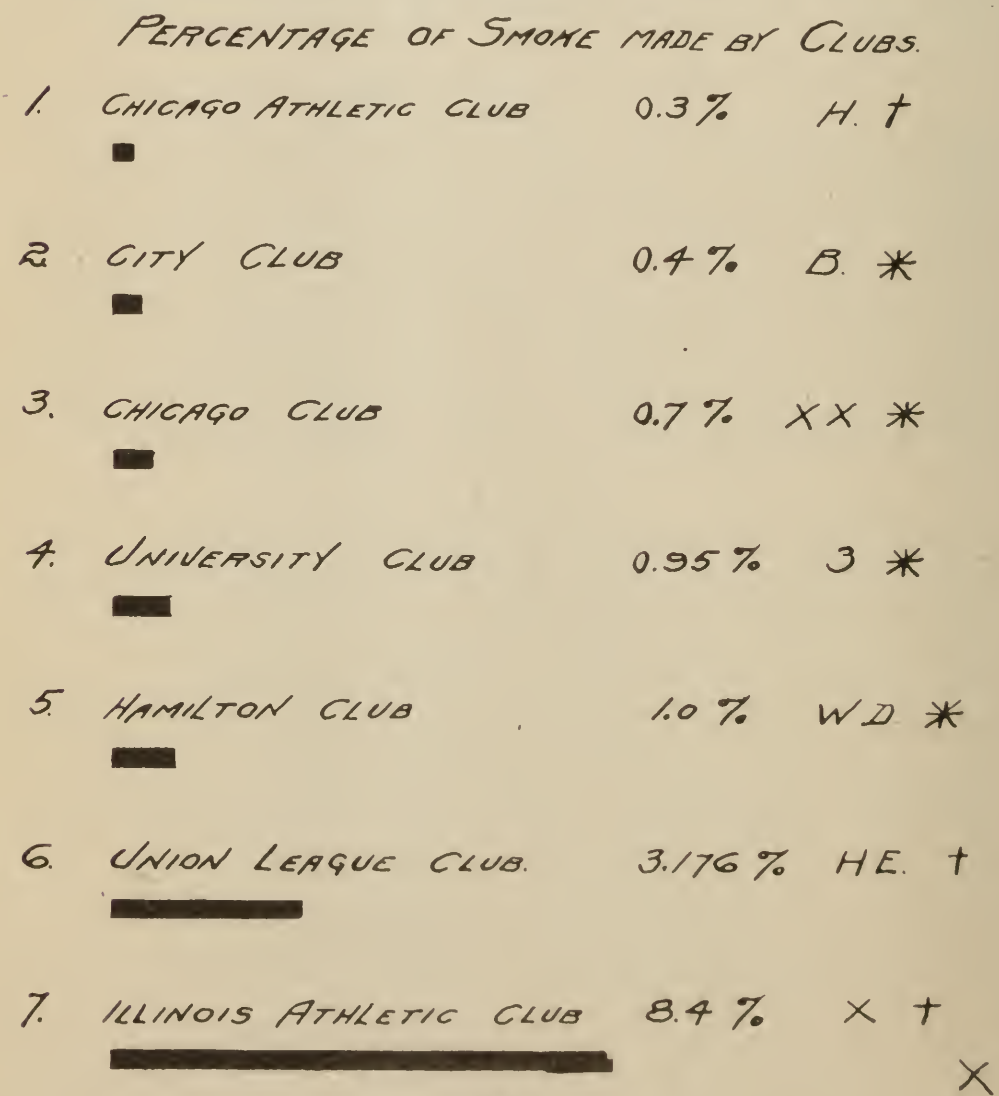


Fig. 2.


SMOKE STANDING OF BREWERIES.
GOOD 2% BAD
DENSITY
GOOD 2% BAD
DENSITY
BARTHOLOMAE NOT RUNNING .0 %
FORTUNE STEEL C.G .0 %
SEIPPS CG .095 %
SCHOENHOFFEN EAST STACK CG .105 %
INDEPENDENT CG .14 %
WEST SIDE CG .165 %
UNITED STATES CG .35 %
SCHOENHOFFEN WEST C.G .405 %
SOUTH SIDE B .41 %
WHITE EAGLE -XX 1.06 %
STEGER X 1.185 %
EAGLE NORTH XX 1.20 %
HOME H 1.40 %
WM. PFEIFER -XX 1.45 %
ATLAS X 1.50 %
HOFFMAN CG 1.55 %
MUTUAL -XX 1.60 %
GEO J. COOK HE. 1.665 %
MONARCH -XX 1.72 %
WACKER-BIRK H 1.895 %
NORTHWESTERN McM. 2.05 %
McAVOY HE. 2.49 %
PILSEN X 2.50 %
BEST X 2.56 %
GAMBRINUS X 2.89 %
NATIONAL X 2.95 %
EAGLE SOUTH STACK XX 3.10 %
TOSETTY -XX 3.30 %
BRAND H 3.93 %
CHICAGO H 4.60 %
TOSETTY BRICK -XX 4.85 %
MULLEN XX 4.89 %
PETER HAND X 4.96 %
CITIZENS McM 5.375 %
HOERBER -XX 5.43 %
MANHATTAN H 5.59 %
FORTUNE BRICK M 5.65 %
KEELEY -XX+H 5.65 %
GOTTFRIED CG. 5.77 %
GARDEN CITY M. 5.86 %
BIRK BROS. XX2. 7.4 %
RUEHL H 9.63 %
STANDARD -XX 11.4 %
STENSON -XX 14.1 %

Fig. 3.

SMOKE STANDING OF DEPARTMENT STORES.

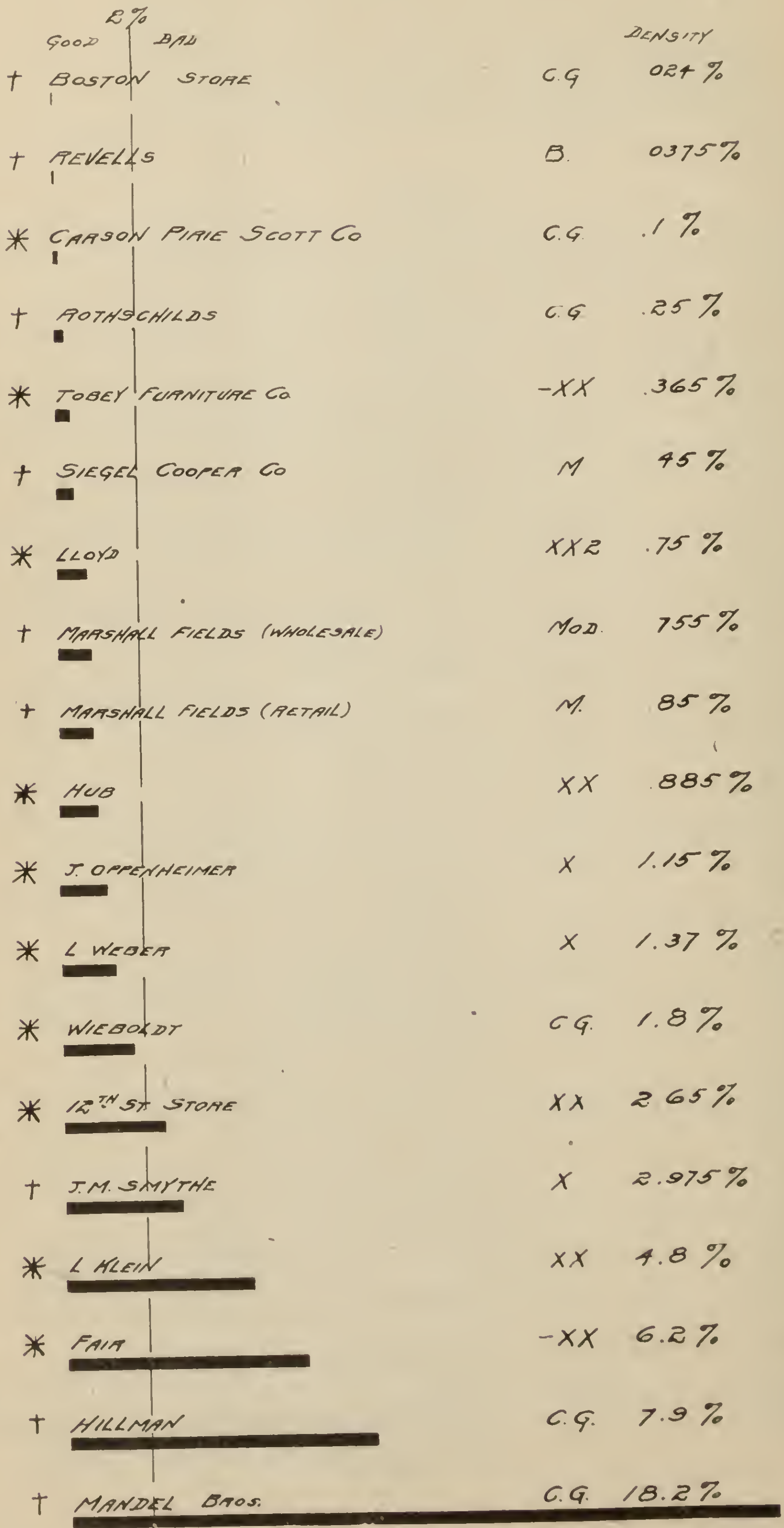
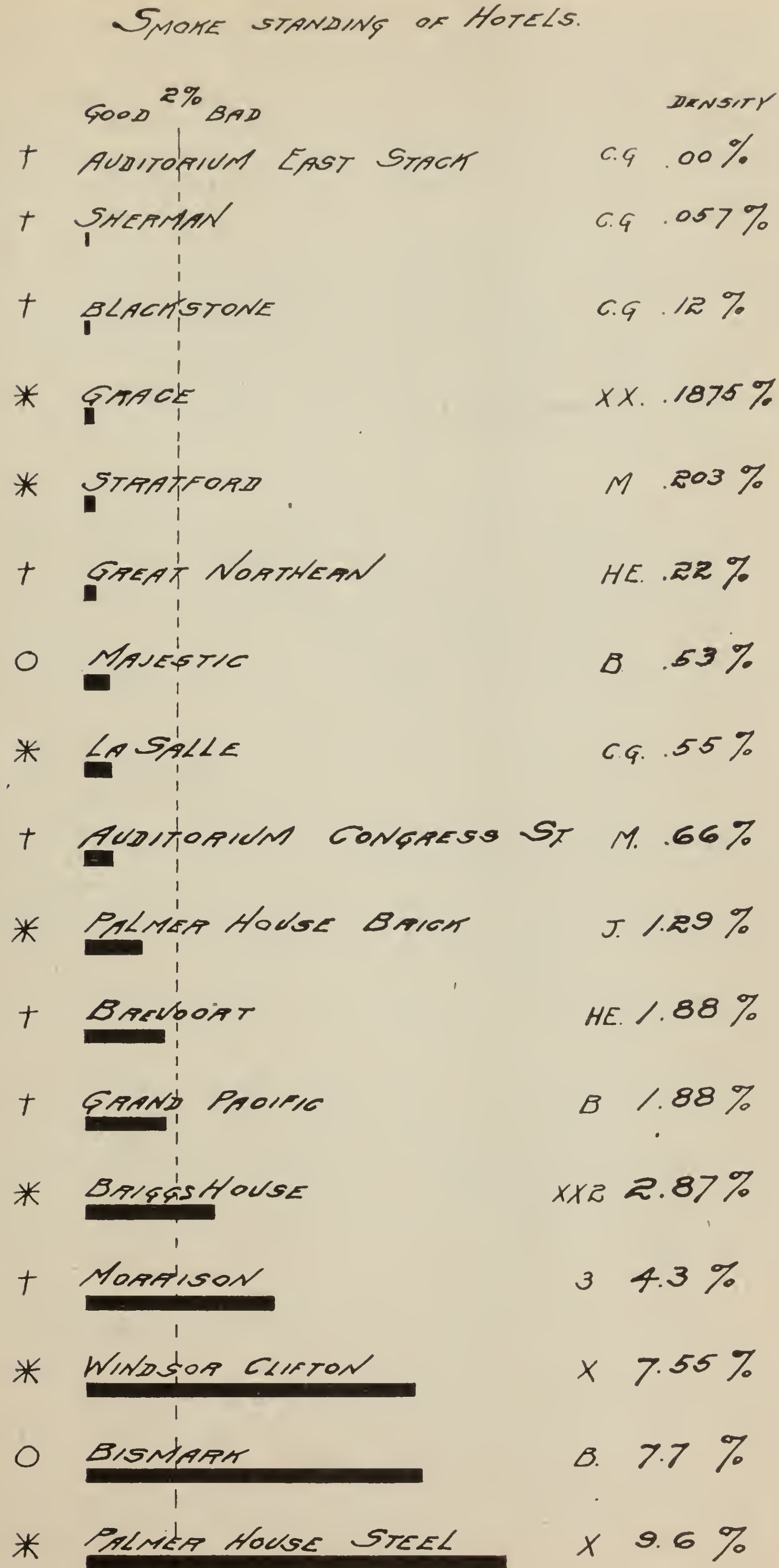


Fig. 4.



SMOKE STANDING OF HOTELS.
GOOD 2% BAD
DENSITY
† AUDITORIUM EAST STACK C.G .00 %
† SHERMAN C.G .057 %
† BLACKSTONE C.G .12 %
✳ GRACE XX. .1875 %
✳ STRATFORD M .203 %
† GREAT NORTHERN HE. .22 %
○ MAJESTIC B .53 %
✳ LA SALLE C.G. .55 %
† AUDITORIUM CONGRESS ST M. .66 %
✳ PALMER HOUSE BRICK J. 1.29 %
† BREVOORT HE. 1.88 %
† GRAND PACIFIC B 1.88 %
✳ BRIGGS HOUSE XX2 2.87 %
† MORRISON 3 4.3 %
✳ WINDSOR CLIFTON X 7.55 %
○ BISMARK B. 7.7 %
✳ PALMER HOUSE STEEL X 9.6 %

Fig. 5.

density of the smoke for the day, which is in fact the measure of the desirability or undesirability of the stack, but it also gives the number of violations per hour of the stack, if any. Readings of this nature taken in the past 6 months have been classified according to industries and charted for closer study. The illustrations, Figs. 2 to 5, and Plates II and III in this paper, show a few of the classifications and the method of charting them. A standard of 2% density for a day's observation was taken to represent good performance. It will be noted that the 2% line is shown on each of these charts; anything under 2% being considered exceptionally good and anything above 2% being considered subject to criticism. This you will note is entirely independent and separate of any consideration of whether or not a stack actually violated the Ordinance.

USE OF THE CHARTS.

The method of making use of this tabulated information is as follows: In working on, for instance, the clubs of the city, a copy of the chart is shown to the offender at the foot of the list and an appeal to his civic pride is made, which in most cases is sufficient to get satisfactory action. In regard to the Illinois Athletic Club, whose smoke standing in the summer of 1912 is shown in Fig. 3, it may be said that this record was sufficient to clean up the plant, and a smoke density of less than 2% is now being realized.

In approaching an industry such as a piano factory for instance, which is making too much smoke, the Department first picks out a factory in the same line of business, which has as nearly as possible the same boiler equipment, and lays the facts before the offending corporation, in effect, for instance, that whereas their piano factory is running, say, 18% or 19% smoke density on a day's observation, the piano factory across the street, a competitor of theirs, is running inside of 0.5 of 1% density, and that from the Smoke Department's standpoint there is no reason why their piano factory cannot be run as clean as another piano factory, provided they will put their plant in proper shape. This argument seldom fails to get the desired results without suit or threat of suit.

The information contained in the tabulated list is of great value in combating claims of plant owners when they make the assertion that their plants do not smoke. One of the most common statements made to the Department is that the owners do not believe the plant is smoking and that, compared with a similar line of industry, their stack is much better than their competitors. In one instance a brewery manager made this statement, and if it had not been for the tabulated information on file it would have been very difficult to convince this party that he was not right. In using the information for the benefit of this brewery manager, it was pointed out to him that he stood between 36 and 40 on a list of 44 breweries with regard to smoke, and this statement was backed up

by a blue print of the chart showing the smoke standing of the breweries and by copies of the Ringelmann chart readings made on his stack for several months past. When this manager realized that of 44 breweries in the city, 35 or 36 of them were making less smoke than he was, he capitulated, and in the near future his entire boiler plant will be rebuilt in the effort to get to the top of the list.

HIGH STANDARD MAINTAINED FOR NEW PLANTS.

The Smoke Department is holding every new plant built in the city of Chicago to a standard of 2% smoke density on 10 hours

Certificate of Operation Release

Name *Holmes, Pyott & Co.* Address *159 N. Jefferson Street*

File No. *628* Permit No. *1176* Issued *4/23/12*

Boiler No. *2* Size and Type *225 H. P. Geary W. T.*

Equipped with *Tile Roof and Deflection Arch*

Date of Internal Inspection *5/6/12*

I have personally seen the furnace in operation, carrying the regular working load and know that with proper handling it can be operated within the City Smoke Ordinance.

Remarks: Describe conditions of furnace or furnaces, fuel, load, operation, etc., at time plant came under your observation.

August 5, 1912.

I was in this plant about an hour and a half today; they are carrying their regular load on this new unit. This is the third time I have been in the plant since the new unit was started and each time they have had a different fuel. Many observations of the stack have shown it to be clean and using the different kinds of coal. A seven-hour Ringelmann chart reading on this stack shows absolutely clear. I therefore suggest that a Certificate of Operation be issued. (Signed) W. A. PITTSFORD.

Certificate of Operation May Be Issued.

(Signed) *O. Monnett*
Smoke Inspector.

(Date) *8/6/12*

Certificate No. *969*

December, 1912

observation before issuing a Certificate of Operation, as provided for in the Ordinance. That this standard is not unreasonable, even in the hand-fired installations, may be realized when it is stated that with approximately 250 new plants which have been installed under permit since the first of January, 1912, practically all of them that have been put in operation are able to show this low density on a Ringelmann chart. Those which do not show this density are studied with a view to improving conditions and no Certificate of Operation is issued until this standard is reached. For the purpose of keeping track of this work, a form of Certificate of Operation Release has been prepared and is shown herein. This certificate, after giving the type of boiler and furnace, provides for a statement by the engineer of the district that he has personally seen the furnaces in operation, carrying their regular working load, and that he knows personally that the plant can be operated inside the Ordinance. To this form is attached a Ringelmann chart reading showing a day's observation with 2% density or less; the Certificate is then issued, a copy of the Ringelmann chart going to the plant owner with a statement that this is the standard which the Smoke Department will expect the plant to maintain in the future. As the Ringelmann chart is taken with the full knowledge of the operators, it really sets a mark for them to maintain, and any deviation from it is quickly noticed by the Smoke Department and followed up until the plant is clean at all times.

METHOD OF HANDLING RAILROAD DATA.

The same plan of using the good performance of one company to spur others to better work is being pursued in the railroad campaign. In the fall of 1910 series of railroad readings were made showing the smoke conditions at the various railroad centers, and a table showing the smoke standing of the railroads was prepared. In the fall of 1911 a similar set of figures was prepared. It soon became evident that there was an intense rivalry among the various railroads in their efforts to be at the top of the list. This has been taken advantage of with good effect by the Smoke Department. Herewith is presented a series of railroad smoke readings for the summer of 1912, which are the first summer readings that have been taken by the Department. It has long been realized that railroad smoke appeared heavier in summer than during the cold weather, but it was not known how much the weather affected smoke densities. Taking the smoke readings of the fall of 1911 as a criterion, and assuming the same effort on the part of the railroads to keep down smoke, the summer readings of 1912 show that there is approximately 100% difference in the smoke density of railroad smoke in the summer over the winter months.

DATA OF HELP TO RAILROADS IN SOLVING DIFFICULTIES.

The railroad readings are furnished here in more detail than has been presented before, as it has been found that the more in-

formation the Department can convey to the railroads the better the results. For instance, by giving the smoke densities for the various locations, a railroad may find that its per cent density at a certain point is very satisfactory, whereas at another railroad center it is not at all satisfactory. By analyzing these smoke density reports for the various localities, a railroad is enabled to determine the points where their engines need special attention and to discover why it is that they cannot have a uniform smoke density throughout the city. Theoretically, if one railroad is inside of 5% density there is no reason why all the rest of them should not be, but practically it does not seem to work out in this way; there is a difference in organization, difference in methods, difference in service performed, and difference in condition of equipment, which seems to have an immense amount of influence on the smoke densities of the various roads. However, it would seem logical to suppose that if uniform methods of enforcing the anti-smoke rules were adopted by all the roads, and if standard equipment in various classes of service was provided, that uniform results could be obtained throughout the city and the smoke kept down to the commercial minimum.

SPECIAL LOCOMOTIVE OBSERVATIONS, 1912.

Railroad.	No. of Observations.	Engine Minutes.	Smoke Units.	Percent. Density.
June 4, 1912, South End of Union Station—				
C., M. & St. P.	3	5	1	4
C., B. & Q.	78	213	55	5.16
Pennsylvania	115	236	92	7.79
C. & A.	20	52	53	20.4
Total	216	506	201	7.94
June 5, 1912, La Salle Station—				
C., B. & Q.	2	24	0	0
C., I. & S.	8	70	14	4
N. Y. C. & St. L.	8	57	20	8.77
C., R. I. & P.	51	250	115	9.2
L. S. & M. S.	62	368	261	14.18
C. & E. I.	6	73	41	11.23
Total	137	842	451	10.59
June 13, 1912, C. & N. W. Passenger Terminal—				
C. & N. W.	174	375	134	7.15
Total	174	375	134	7.15
June 25, 1912, R. I. & L. S. Station, Englewood—				
Pere Marquette	1	2	0	0
C. I. & S.	2	2	1	10
C. & E. I.	9	10	5	10
N. Y. C. & St. L.	12	18	9	10
L. S. & M. S.	26	47	30	12.77
C. R. I. & P.	55	135	106	15.7
Pennsylvania	41	73	96	26.3
Unidentified	1	1	4	80
Total	147	288	251	17.43

Railroad.	No. of Observations.	Engine Minutes.	Smoke Units.	Percent. Density.
July 1, 1912, Ada St., Pan Handle, St. P. and C. & N. W. Rys.—				
C. M. & St. P.	62	70	36	10.29
C. & N. W.	94	110	67	12.18
Pennsylvania	114	251	193	15.35
Total	270	431	296	13.73
July 2, 1912, Sixteenth and La Salle Sts., I. C. R. I. Crossing—				
C. B. & Q.	10	15	0	0
Pennsylvania	1	1	0	0
Erie	3	4	1	5
L. S. & M. S.	51	71	27	7.61
C. & N. W.	7	12	5	8.33
Michigan Central	2	2	1	10
C. G. W.	2	2	1	10
Pere Marquette	3	6	3	10
Wabash	3	6	3	10
Illinois Central	18	32	18	11.25
A. T. & S. Fe.	4	5	3	12
N. Y. C. & St. L.	11	20	13	13
C. R. I. & P.	64	125	83	13.28
W. C.	5	6	5	16.66
C. & E. I.	10	15	13	17.33
C. I. & S.	5	8	9	22.5
Grand Trunk	1	1	3	60
Total	200	331	188	11.33
July 3, 1912, Seventeenth St. and C. & W. I. R. R.—				
C. B. & Q.	1	1	0	0
Belt	11	15	3	4
A. T. & S. Fe.	11	19	4	4.21
C. & E. I.	9	27	8	5.92
C. I. & L.	16	35	13	7.43
C. R. I. & P.	7	16	7	8.75
N. Y. C. & St. L.	6	8	4	10
C. & N. W.	5	11	6	11
Erie	20	48	27	11.25
Illinois Central	18	28	20	14.29
Grand Trunk	17	28	21	15
Wabash	24	40	34	17
Michigan Central	1	1	1	20
C. & W. I.	6	6	6	20
Wisconsin Central	6	15	30	40
Total	158	298	184	12.34
July 8, 1912, Fifteenth St. and C. & W. I. R. R.—				
C. & O.	2	2	0	0
L. S. & M. S.	1	1	0	0
A. T. & S. Fe.	38	60	13	4.33
Wisconsin Central	4	4	1	5
Illinois Central	5	12	4	6.33
C. & E. I.	51	188	92	9.77
Grand Trunk	36	57	33	11.58
C. & W. I.	9	9	6	13.33
C. M. & St. P.	2	3	2	13.33
C. R. I. & P.	14	15	11	14.66
Erie	32	80	78	19.5
Unidentified	1	4	4	20

Railroad.	No. of Observations.	Engine Minutes.	Smoke Units.	Percent. Density.
C. I. & L.	10	13	15	23.15
Wabash	57	93	118	25.37
Belt	14	18	23	27.00
Total	276	559	400	14.31
July 17, 1912, Michigan Avenue and C. & W. I. R. R.—				
Belt	29	56	69	24.64
C. & E. I.	21	55	75	27.27
C. & W. I.	1	2	4	80
Total	51	113	148	26.19
July 19, 1912, Kedzie Avenue and C. & N. W. Ry.—				
C. R. I. & P.	2	10	0	0
C. & N. W.	128	290	176	12.14
Total	130	300	176	11.73
July 23, 1912, Sixty-third and I. C. R. R.—				
Illinois Central	150	383	146	7.65
Michigan Central	16	24	14	11.66
Total	166	407	160	7.86
July 25, 1912, Forty-ninth and Kedzie Avenue, Grand Trunk Ry.—				
L. S. & M. S.	1	1	0	0
A. T. & S. Fe.	6	19	8	8.42
Grand Trunk	92	185	137	14.81
C. I. & S.	1	2	2	20
Michigan Central	3	8	11	27.5
C. M. & St. P.	1	1	2	40
Total	104	216	160	14.81
July 31, 1912, Forty-first and Lake Avenue—				
Michigan Central	7	28	7	0.5
Illinois Central	12	24	23	19.16
Total	19	52	30	11.54
August 14, 1912, 79th St. and C. & W. I. & Rock Island R. R.—				
L. S. & M. S.	3	3	1	6.66
C. I. & L.	2	3	1	6.66
C. & W. I.	6	6	3	10
C. & E. I.	9	11	7	12.73
Belt	65	120	97	16.16
C. R. I. & P.	32	38	32	16.84
N. Y. C. & St. L.	5	5	6	24
Wabash	1	1	2	40
Erie	3	9	23	51.11
Total	126	196	172	18.06
August 22, 1912, Western Ave., B. & O. C. T. & C. & N. W. Ry.—				
C. I. & L.	2	6	0	0
L. S. & M. S.	1	5	0	0
Michigan Central	2	9	0	0
Erie	4	9	2	4.44
C. G. W.	6	10	4	8
B. & O. C. T.	27	57	24	8.42
Pennsylvania	6	21	11	10.48
C. & N. W.	114	438	423	19.27

Railroad.	No. of Observations.	Engine Minutes.	Smoke Units.	Percent. Density.
N. Y. C. & St. L.	1	3	3	20
B. & O.	3	7	8	22.85
Total	166	565	475	16.81
August 23, 1912, Western Avenue and C. B. & Q. R. R.—				
Michigan Central	2	3	0	0
Illinois Central	2	40	1	0.5
C. B. & Q.	132	576	53	1.84
B. & O. C. T.	8	21	3	2.85
C. & E. I.	6	20	3	3
C. R. I. & P.	3	11	3	5.45
Pere Marquette	4	14	4	5.71
Wabash	4	13	5	7.7
C. R. & I.	7	44	22	10
C. M. & St. P.	9	68	37	10.88
C. I. & L.	5	17	15	17.64
C. & N. W.	3	4	4	20
N. Y. C. & St. L.	1	2	2	20
Erie	5	10	11	22
C. I. & L.	10	41	51	22.17
Pennsylvania	4	5	8	32
Total	205	894	222	4.96
August 30, 1912, Forty-seventh St. and C. & W. I. R. R.—				
A. T. & S. Fe.	2	6	0	0
C. & N. W.	1	1	0	0
C. M. & St. P.	2	2	0	0
C. R. I. & P.	1	1	0	0
Grand Trunk	21	40	10	5
Wabash	37	117	35	6
C. R. & I.	5	11	4	7.27
C. & W. I.	8	10	7	14
Belt	9	13	10	15.38
Pennsylvania	51	105	87	16.57
C. I. & L.	2	2	2	20
C. & E. I.	7	9	10	22.22
Erie	14	23	55	47.82
Pere Marquette	2	2	5	50
C. B. & Q.	2	2	6	60
Total	164	344	231	13.42
September 3, 1912, Sixteenth and Stewart Avenue—				
Grand Trunk	1	1	0	0
Illinois Central	1	1	0	0
L. S. & M. S.	2	7	0	0
C. B. & Q.	70	150	12	1.6
C. & N. W.	17	45	4	1.77
C. G. W.	14	24	6	5
Pennsylvania	62	131	33	5.8
C. R. I. & P.	2	5	2	8
C. M. & St. P.	8	18	9	10
N. Y. C. & St. L.	2	4	2	10
C. & A.	8	8	4	10
B. & O. C. T.	8	13	9	13.84
Pere Marquette	5	17	12	14.12
B. & O.	29	75	84	22.4
Total	229	499	177	7.09

Railroad.	No. of Observations.	Engine Minutes.	Smoke Units.	Percent. Density.
September 4, 1912, Van Buren St. and I. C. R. R.—				
A. T. & S. Fe	5	13	0	0
Pennsylvania	1	3	0	0
Wisconsin Central	3	6	1	3.33
C. B. & Q.	3	9	2	4.44
Illinois Central	198	383	105	5.48
Michigan Central	8	17	5	7.14
Total	218	431	113	5.26
September 6, 1912, Forty-sixth Avenue and Twenty-second Street—				
C. G. W.	1	7	0	0
Illinois Central	2	5	1	4
Wisconsin Central	3	6	2	6.66
B. & O. C. T.	3	11	6	11.
Belt	89	241	195	16.18
Manf. Junction	8	13	14	21.53
Total	106	283	218	15.4
September 25, 1912, Twenty-sixth Street and Pan Handle R. R.—				
C. R. I. & P.	1	3	0	0
C. G. W.	8	18	3	3.33
C. & A.	11	43	10	4.65
C. M. & St. P.	14	33	9	5.45
Michigan Central	2	4	2	10
C. I. & S.	6	19	10	10.52
C. I. & L.	4	12	8	13.33
N. Y. C. & St. L.	3	6	4	13.33
C. B. & Q.	20	77	53	13.76
B. & O.	13	26	18	13.84
C. & N. W.	20	71	52	14.64
Illinois Northern	57	164	147	17.92
Pennsylvania	40	138	152	22.02
B. & O. C. T.	7	15	17	22.66
C. R. & I.	3	9	13	29
Erie	2	6	10	33.33
Chicago Junction	3	5	9	36
Total	214	649	517	15.93
September 26, 1912, C. & A. and Pan Handle Crossing—				
C. & E. I.	1	3	0	0
C. I. & L.	1	1	0	0
C. R. I. & P.	1	1	0	0
L. S. & M. S.	2	3	0	0
N. Y. C. & St. L.	1	1	0	0
Wisconsin Central	3	7	1	3
C. B. & Q.	9	20	7	7
C. M. & St. P.	11	25	9	7.2
C. G. W.	7	11	5	9.09
C. & A.	30	68	35	10.29
B. & O.	10	25	16	12.8
Erie	4	4	3	15
Pennsylvania	28	59	49	16.61
B. & O. C. T.	5	9	8	17.77
Illinois Central	2	3	3	20
Michigan Central	2	2	2	20
C. & N. W.	10	17	19	22.35
Chicago Junction	11	28	32	22.86

Railroad.	No. of Observations.	Engine Minutes.	Smoke Units.	Percent. Density.
C. I. & S.	3	6	7	23.33
C. R. & I.	9	20	24	24
Pere Marquette	2	3	5	33.33
Wabash	2	4	7	35
Total	154	320	232	14.5
September 27, 1912, Root Street and Rock Island R. R.—				
L. S. & M. S.	35	78	14	3.59
C. I. & S.	3	3	1	6.66
C. R. I. & P.	40	111	42	7.56
C. & A.	5	20	9	9
N. Y. C. & St. L.	7	12	7	11.66
C. G. W.	2	3	2	13.33
C. & E. I.	7	9	8	17.77
C. & N. W.	7	10	8	11
C. B. & Q.	2	2	3	30
Total	108	248	94	7.58
September 30, 1912, Eighty-sixth and Superior Streets, Rock Island Junction, South Chicago—				
Illinois Central	1	8	0	0
C. & W. I.	6	41	19	9.27
Belt	21	93	61	13.12
Pennsylvania	26	63	61	19.36
L. S. & M. S.	13	22	22	20
B. & O.	30	84	101	24.04
C. R. I. & P.	18	71	108	30.42
E. J. & E.	38	180	282	31.33
C. Short Line	1	4	8	40
Total	154	566	662	23.39

Summary.

Smoke Densities at Various Locations.

Date.	Location.	Percentage.
June 4.	South End Union Station	7.94
June 5.	La Salle Station	10.59
June 13.	C. & N. W. Passenger Terminal	7.15
June 25.	Englewood Union Station	17.43
July 1.	Ada St., Pan Handle, St. P. & N. W. Ry	13.73
July 2.	Sixteenth and La Salle Sts	11.33
July 3.	Seventeenth and C. & W. I. Railroad	12.34
July 8.	Fifteenth St. and C. & W. I. Railroad	14.31
July 17.	Michigan Avenue and C. & W. I. Ry., Kensington	26.19
July 19.	Kedzie Avenue and C. & N. W. Ry	11.73
July 23.	Sixty-third Street and I. C. Railroad	7.86
July 25.	Forty-ninth and Kedzie Avenue	14.31
July 31.	Forty-first and Lake Avenue	11.54
Aug. 14.	Seventy-ninth and C. & W. I. & R. I. R. R.	18.06
Aug. 22.	Western Ave. and B. & O. C. T. & C. & N. W. Ry	16.81
Aug. 23.	Western Ave. and C. B. & Q. R. R.	4.96
Aug. 30.	Forty-seventh and C. & W. I. R. R.	13.42
Sept. 3.	Sixteenth and Stewart Avenue	7.09
Sept. 4.	Van Buren Street and I. C. R. R.	5.26
Sept. 6.	Forty-sixth Avenue and Twenty-second Street	15.04
Sept. 25.	Twenty-sixth Street and Campbell Avenue	15.93
Sept. 26.	C. & A. and Pan Handle Crossing	14.05

Sept. 27. Root Street and C. R. I. & P. R. R. 7.48
Sept. 30. 86th and Superior Ave., Rock Island Junction, South Chicago 23.39

Smoke Standing of the Various Railroads in the Summer of 1912.

	Railroad.	No. of Observations.	Engine Minutes.	Smoke Units.	Percent. Density.	Standing 1911.
1.	C. B. & Q.	329	1,089	191	3.51	1
2.	A. T. & S. Fe	66	122	28	4.75	3
3.	C. G. W.	40	75	21	5.6	8
4.	Illinois Central	409	919	321	6.98	11
5.	Michigan Central	45	98	43	8.98	15
6.	C. M. & St. P.	112	225	105	9.36	2
7.	N. Y. C. & St. L.	57	136	70	10.3	20
8.	B. & O. C. T.	58	126	67	10.63	7
9.	L. S. & M. S.	197	606	355	11.55	10
10.	C. & A.	74	191	111	11.62	25
11.	C. I. & L.	42	89	54	12.15	18
12.	C. & W. I.	36	74	45	12.16	21
13.	C. I. & S.	38	156	95	12.18	22
14.	C. & E. I.	136	420	262	12.47	24
15.	C. R. I. & P.	291	792	509	12.85	14
16.	C. & N. W.	580	1,384	898	12.94	5
17.	Grand Trunk	168	312	204	13.08	17
18.	Pere Marquette	17	44	29	13.18	12
19.	Pennsylvania	489	1,086	782	14.4	9
20.	Wabash	128	274	204	14.89	16
21.	C. R. & I.	24	84	63	15	28
22.	Belt Ry.	238	556	458	16.87	13
23.	Illinois Northern	57	164	147	17.92	29
24.	Wisconsin Central	24	44	40	18.18	4
25.	B. & O.	85	217	227	20.92	6
26.	Mfgrs. Junction	8	13	14	21.54	Not Listed
27.	Erie	87	193	210	21.76	19
28.	Chicago Junction	14	33	41	24.84	26
29.	E. J. & E.	38	180	282	31	30
30.	Unidentified	2	5	8	32	23
31.	Chi. Short Line	1	4	8	40	Not Listed
	Total	3,890	9,721	5,892	12.12	

Discussion.

A Bement, M. W. S. E. (Chairman): This Society has at different times taken up subjects of interest to the community,—subjects especially along engineering lines,—and has done a great deal of original work through its membership. The subject of aviation is one. The papers which the Society has published after presentation by its members make a volume of literature larger, I think, than that of any other American engineering society. On the subject of smoke, too, we have a number of very good individual papers and we have had the chief smoke inspector under one administration before us on two occasions. This year we have another inspector, and he appears before us tonight with a paper for the first time. Both of these gentlemen are engineers of a high type,—a much higher type than we find in the position of smoke inspector in other cities. The reason we have had and now have

men of this character and type is that the education of the public in matters of engineering has been such that there was a demand some six years ago for a smoke inspector whom people would consider an engineer, and a man of that character, a member of this Society, was appointed.

Osborn Monnett: This paper outlines an attempt of the Smoke Department to classify and tabulate smoke offenders, and in a way reduce their smoke standing to a mathematical standard for the purpose of comparison and study. So far as I know, it is the first attempt of this kind ever made, and I believe the results amply justify the time and trouble of the Smoke Department to get this information. As time goes on, every Ringelmann chart that the department makes for any purpose whatever will be filed, cross-filed, and indexed alphabetically and numerically, so that the record will be available for study in the future. These Ringelmann charts are especially valuable in talking to the plant owners who have no idea of how much smoke they make, and when they find that we have got their plant mathematically classified in relation to all the other plants of a similar character, we generally get what we want.

L. P. Breckenridge, ASSOC. W. S. E.: I have examined with much interest the paper by Mr. Monnett entitled New Methods of Approaching the Smoke Problem, and am very glad indeed that the experience of the Chicago Smoke Department has led it to the adoption of a policy of educating the public in the methods of preventing smoke. Several years ago, when the smoke problem was rigidly adopted in Chicago, that method seemed to the writer to be the only method which would produce satisfactory results. I have watched the work and development of the Chicago Smoke Department with continued interest during the last five or six years, and I frequently said that the work it had accomplished was more permanent and had produced better results than any other municipal scheme with which I was acquainted.

I am also glad to see the classification of various industries arranged in the order of the amount of smoke made by the different companies. I think this is a very good scheme. It produces what you might call an honor list and everybody can see just where he stands and whether he is on the good or bad side of the line. It also gives the Smoke Department some basis to work on, inasmuch as we would naturally expect them to clean up the worst offenders.

The smoke problem is one that will be with us for many years and it will only be by keeping everlastingly at it that we can expect to keep our cities reasonably free from smoke.

The work of the Chicago Smoke Department has, it seems to me, been well carried on and I trust they will not be discouraged in well doing.

A. Bement: The education of people, the human race, of ourselves, in the matter of smoke, has been, since the earliest times,

a slow process, and it is natural that it should have been. From earliest times, from childhood, smoke has been considered a necessary accompaniment of fire. We may search through history, and it all indicates that smoke necessarily accompanies fire,—that we can not have fire without smoke. Until the past hundred years I think we would have to concede that all teaching, and all evidence as far as known, pointed to the supposed fact that smoke was a necessary accompaniment of fire. Then, too, smoke is not always objectionable. Were you ever in the country taking a long drive,—a drive that you thought would never terminate,—and then at last see a smoking chimney, an evidence of civilization and that you were getting to your destination? Certainly it looked very pleasant, and it did not at that time present itself as an objectionable feature. Then, again, at sea, is not the smoke on the horizon quite an agreeable sight? We are glad to see it, because it indicates the presence of another ship.

But some things, even good things, if we have too much of them, get to be unpleasant. We have come gradually and very slowly to a realization that smoke is not necessary and that too much of it is a very bad thing, and any of it in some places is always objectionable. When it is away off in the distance and it is a signal to us, it is not objectionable, although it may be so to the people in its vicinity. At sea the steamer in the distance, pouring out a heavy volume of black smoke objectionable to the passengers on that steamer, is a pleasant thing to us, for we are not cognizant of the unpleasant feature of the soot falling on the passengers of the steamer. So the nearer we get to smoke, the more unpleasant it becomes.

Gradually the theory that smoke was not necessary began to be exploited. Mr. C. Y. Williams wrote a book on the subject, and some other people followed with remarks about it; but I think it is only within the past ten years that all the requirements for smokeless combustion were defined. William Kent first put together what we might consider the best definition of requirements for smokeless combustion, in which he insisted that coal should be volatilized "slowly." He meant uniformly. When we corrected that feature of his definition, about ten years ago, we made another advance. So it is only within the last ten years that any of us could prove that the real method of preventing smoke was explained sufficiently for people who were not experts to make use of it. The average manufacturer,—the man who owned the plant and was responsible for the smoke,—was quite dependent upon the old idea that had always prevailed that fire must make smoke.

In England some centuries ago, when coal was a new thing, they did not have a smoke ordinance, but they had what we might call a coal ordinance. At one time they prohibited people using coal during the period of Parliament; at another time, this prohibi-

tion was enforced when Queen Elizabeth was in London. Then there was a time when a law with a very severe penalty was in force which provided that the man who burned "sea coal" (which was coal from the first mines, which happened to be at the sea coast) would be hung, and history says one man was hung. They did not realize that they could have a smoke ordinance, and thereby prevent smoke, but they thought that the only way to prevent smoke was to stop burning coal. So that until within recent times some have felt that agitation against smoke meant opposition to bituminous coal.

That was the way the average man has looked at the matter, and he considered the Smoke Department to be a sort of political blackmailing outfit and allowed himself to believe that smoke could not be stopped. So there was a time when this was an honest feeling, and the idea became thoroughly embedded in his consciousness even after he knew that smoke could be stopped, and that there was no reason for continuing to make it; and it was quite a habit to try to put off the smoke inspector, to tell him something was being done, tell him they were doing "everything possible" and "spending a large sum of money," when the sum was perhaps two dollars, or a few cents, or nothing at all. But gradually the people have come to realize that the Smoke Department has a just and genuine reason for its existence, and that it asks nothing unreasonable. So, a great deal has been accomplished in educating the citizens along right lines.

Much has been said about the financial loss due to smoke. In this connection I recall being in Cincinnati some years ago. I started out in the morning with a clean shirt, a clean collar, and a clean pair of cuffs. I returned to the hotel at lunch time and replaced the cuffs and collar with fresh ones, because the others were very much soiled. I did the same thing in the evening. The shirt also was soiled enough to take off before evening. That made three collars, three pair of cuffs, and one shirt in one day. We all know that Pittsburgh has been the standard for the smoke joker, but I do not think Pittsburgh has ever been as smoky as Cincinnati. I do not know what the conditions in Cincinnati are now, however, as I have not been there recently.

A gentleman who conducts one of the stores on State street, said there was a loss of ten million dollars per annum in Chicago from smoke. Others have figured as low as seven, and some have figured above ten million dollars. This evening, before coming to the meeting I made some figures based on my experience in Cincinnati, and I have applied the figures to Chicago, assuming the same smoke conditions as at Cincinnati. The cost for laundering three collars at 2½c apiece, three pair of cuffs at 5c a pair, and one shirt at 10c, would be 32½c. Under favorable conditions we would expect to use not more than one collar and one pair of cuffs in one

day, and one might wear a shirt two days. Then, 2½c for a collar, 5c for cuffs, and 5c for half a shirt would amount to 12½c, making a difference in cost of laundering of 20c per day, due to such a smoke condition as I have mentioned. Now, if Chicago has a population of 2,250,000, including visitors, and if one in five is a man, and if every fourth man wears a white shirt, collars and cuffs, and makes a presentable appearance as we see people on the city streets, we have 112,500 men wearing white linen. If each pays 20c a day excess for laundering, it amounts to $22,500 a day, and for 365 days we will have an excess laundry bill of $8,212,500. This does not include the ladies' expensive and delicate waists, their white gloves, and many other things.

Paul P. Bird, M. W. S. E.: In these days when we are hearing so much about progressiveness and efficiency, it is gratifying to find out that we have a progressive and efficient Smoke Department. I think that the paper which is presented to this Society tonight shows all the way through that the department is following progressive principles and that all of its work is done in an efficient and careful manner.

I can say some of these things today with a little better grace than I could two or three years ago, and I am glad to say that in my opinion, Chicago is to be congratulated on having this department. I congratulate Mr. Monnett on his paper, which shows that the men under his direction are doing a good work, that it is being done carefully, and in the long run it will be found that a great advance has been made in the work that they are undertaking. It is a great deal of personal satisfaction to me to see that some of the schemes and ideas that we had three or four years ago are working out well.

Professor Breckenridge, in the letter that he has written, has made one statement that might well be the motto of the department, that is, "Keep everlastingly at it." Making these readings every day, tabulating them, and showing the different plants,—just what they are doing and where they are in the list,—is an excellent thing and it is by keeping everlastingly at it that the improvement is brought about.

As you look through this paper and see what it is about, you will note that it has very largely to do with the Ringelmann chart system of reading smoke. In fact, a very large part of the paper is devoted to Ringelmann chart readings and tabulation of results obtained in this way. For the last three or four years I have been much interested in this system of judging the density of smoke. It is the best thing we have and it is being used all over the world, particularly in America. The different universities are using the system, the various smoke departments, the Geological Survey, and it has become the official "measuring stick" of the engineer as far

as this sort of measurement is concerned; but I believe that the manner in which we use it is capable of improvement.

I notice in Fig. 4 that the Grace Hotel has an average density of 0.1875%. So that, reading smoke down to 0.0005 of 1%, is getting it down very fine. When I first came out of school I went to work in a ship yard, where there was an old draftsman or engineer who used to make all the calculations and drawings for the propeller wheels. In doing this he used some very long formulas. They were empirical formulas and there were many things that were assumed. This old gentleman, in making his calculations, would put down a set of data and assume four or five different constants. After he had these figures down he would get a six-place table of logarithms and work out the answer. It seems to me, that in making Ringelmann chart readings, as reported in this paper, with smoke stacks of many different sizes and different heights, with the wind and other atmospheric conditions continually changing and only recording the density in units of 20%, and then working out the results as close as 0.0005 of 1%, the process is about as inconsistent as the illustration referred to. You will notice how very low all these percentages are. The measuring scale that the man used is only graduated in units of 20%, and yet these averages are all around 2, 3 and 5%. In a city like Chicago, where so much has been done to stop smoke, the Ringelmann chart should be used in some other way than we are using it today. In my opinion it would be better to get away from the No. 1, 2, 3, 4 and 5, and read directly in percentages. It is like giving a man a stick that has marks on it 6 in. apart, and then giving him a lot of little blocks that are about ½ in. or ⅝ in. long, giving him one at a time and taking one away before giving him the next one, and then having him tell you the length of each block. This is not an accurate way of measuring anything, and my suggestion is that we have come to a time when we want to do away with the numbers of the different smoke charts and read directly in percentages.

Mr. Bement: Mr. Bird's suggestion is very interesting. The Ringelmann chart advances by five steps, 20% apart. The first one is 20%, and the next one is 40%; there is no 15%, no 25%, and his suggestion points to a chart beginning white at one end and black at the other, with the different densities indicated.

A. L. Rice, M. W. S. E.: It occurs to me that there is one service which the Smoke Department is rendering in all this work, not only to the city of Chicago but to the profession of engineering in general, which ought to be preserved and which I trust is being preserved and may be made public for the benefit of engineers and the community at large, and that is the knowledge of just what is necessary to produce smokeless combustion under different furnace conditions. Unquestionably the study of furnace combustion under all kinds of boilers and with all sorts of fuel, which they must be

making every day, is giving the department engineers an insight into what has to be done which will hardly be found anywhere else in the country, if in the world. While that information is, in a generalized way, perhaps, to be found in some printed form, yet the application to specific cases is always a thing which is difficult. We have certain rules that we try to go by, in regard to the distance of the boiler above the grate, and in regard to the number of cubic feet of space that there shall be in the fire box and in the combustion chamber, and those things may work out in one instance and in another instance they may not, owing to some variation in the condition or the amount of heating surface in the boiler. So that the data which the Smoke Department must be accumulating has unquestionably a tremendous engineering value.

It is not only solving the problem in the city, but it seems to me, if the data can be arranged and analyzed and put into get-at-able form, it will be solving very largely the smoke problem for all of the cities and for the entire country. All our cities, even New York with its previous freedom from smoke, are beginning to feel that the smoke problem is going to be much more serious in the future. With the rise in price of anthracite coal and the exhaustion of supply, and even with the exhaustion in the near future of a good share of the semi-bituminous, we shall be forced in all cities to a larger use of the bituminous coals, and that will mean that the country at large will need just this information which the Smoke Department is accumulating. It seems to me that their method of going at this and helping to solve these individual problems in so many cases, under such varying conditions, is going to be one of the most valuable contributions to engineering literature that we can have, if it can be put into form, and I hope some means may be found of doing that.

Mr. Bement: The last table in Mr. Monnett's paper is very interesting to me,—the standing of the railroads,—and I am personally interested to see the Chicago, Burlington & Quincy Railroad at the head. About twelve years ago I did some work for that road. With Mr. Wickhorst, the engineer of tests, I devoted ten or twelve days testing locomotives. On those tests both of the engines we were comparing were operated under every condition, without smoke. We had a very heavy train, as much as the locomotive would move out of the siding, and we were able to run continuously, under any condition, without any smoke whatever. At times we did so because we wanted to see if it could be done. At other times we found it necessary to do the same thing to get capacity, that we did to get the smokeless condition. So sometimes, in trying to avoid smoke we got good capacity, and at other times, in trying to get a good capacity, the smokelessness was a necessary accompaniment. I am wondering if, after twelve years, I can congratulate myself on any of this C., B. & Q. R. R. performance. Perhaps not. Mr. Wickhorst, however, is no doubt entitled to much credit.

In this connection we have Mr. C. W. Corning, Chief Smoke Inspector of the Chicago & Northwestern Railway, with us this evening. The Northwestern is a high grade corporation, has some splendid depots, runs its trains on time,—which is more than many of the railroads do,—has hauled heavier trains with smaller engines than any other railroad has hauled, and it stands very well in this smoke list. We would like to hear from the inspector of this road.

C. W. Corning: The Chicago & Northwestern Railway selects its men from the ranks. I am a locomotive engineer of fifteen years' running experience, and have been selected as Chief Smoke Inspector. I have six men under me, who are also engineers with the exception of two. They were firemen who failed in the physical examination for promotion.

In the way we used to work, the inspector would go out along the right-of-way and hide behind a box car until some poor fellow came along making black smoke. Then the Master Mechanic would get the report and the man would have to go "on the carpet,"—as the men say, "measure the carpet in the boss' office,"—and after being given the "third degree" and perhaps other things, he was allowed, perhaps, fifteen or thirty days to think about it. We have adopted now another line of procedure. The Smoke Inspector knows all his engines and the man in his territory. He will watch one engine and mark the result in a little book. The next one is treated the same. When he observes smoke, he makes a note of it with the engine number. In this way much data, showing the action of the engines, and performance of each man, is acquired. Perhaps he will watch a man two or three days or a week, and observe that he does no worse, nor does he do any better. So the inspector at the first opportunity gets on the engine and rides with that man. He does not say a word; he just gets up there and rides with him. When any one of the smoke inspectors or myself get on the engine, the fireman is a very busy fellow right away, and in nine out of ten instances he shows a clean stack. Then we just speak to him and say, "Now, you have done a good job of firing this time; do it all the time and you will be out of trouble." This almost always results in continued improvement, but in the event that the man drops back, we will perhaps notify him again. In case this is not effective, he is reported to me, but he is generally given two or three chances, some of the men even more. Much depends on weather conditions, and time of trains,—as the Chairman says, we are always on time, and some of the time is "screwed" up very rapidly.

When a Smoke Inspector rides with a man, he enters in his book the word *instructed*. All reports are made out on a regular printed form after each day's work. Our October report is complete with the exception of the report of one inspector, which is not yet in. During the thirty-one days in October we made 15,159 engine observations, and instructed 174 crews. There have been

27 cases of violation reported. Out of these, 23 men have been disciplined, ranging from one day's suspension to dismissal; one man was dismissed.

Mr. Rice: Those cases were reported by your own men, as I understand it?

Mr. Corning: Yes. I have not with me the city reports of violations that are sent to us. I cannot say just now how many there were. At one time during September and October 35 men had been called in for discipline.

Engineers from the Smoke Department do much to correct stationary plants, but with locomotives there is nothing of this kind; we must study it out ourselves, and I think the problem is solved in the engines using superheat. The superheat engine shows a 25% saving in fuel. The Northwestern's fuel bill for the last year was over eight million dollars, and one can very readily see what 25% saving in fuel will mean. Mr. Quayle, our Superintendent of Motive Power, told me recently that our engines are going to be of the superheat design from now on, and all heavy power that we have at the present time is to be fitted with superheating apparatus as the flue sheets and fire boxes wear out. In superheating an engine, the fire box and flues must be replaced by new ones. The whole inside construction is different.

To determine coal weight on to an engine, we give a fireman a certain sized scoop. We know approximately what every size of scoop will hold; they are numbered 4, 5 and 6. The No. 5 scoop will hold 18 lb. of coal on an average, if it is filled in the ordinary way of firing coal. We count the scoops of coal with little counters which we hold in our hands. I have sat for many miles with one of these in my pocket and told the fireman at the end of the run just how much coal he had used. The water may be measured in the same way.

Mr. Bement: Some people who have been forced to do away with smoke, or to reduce it, have found afterwards that there was quite a gain in efficiency, so that it became an economical measure. Some time ago the Illinois Central Railroad appeared in the public press almost every day for a long time, with some remark about smoke, much to its annoyance. An association here in the city gave special attention to that railroad. It caused the road, however, to give special attention to the smoke problem, and an enormous improvement was made. Some time afterwards the late Mr. Harahan told me that the efforts toward smoke reduction had resulted in quite a material increase in economy, and that this increase in economy, and reduction in coal consumed, had been in itself a very desirable thing, sufficient to justify their effort. This result, I think, applies in nearly every instance.

W. A. Pittsford (Chicago Smoke Department): The records that we are getting are all kept, but the finances of the city are such

that we will probably not get them printed unless we do it ourselves. There is not much enthusiasm in some departments of the city about the Smoke Department. The downtown district, properly called, is from Chicago Avenue on the north to Twenty-Second Street on the south, and Halsted Street to the Lake. That is termed, in our office, the thirty-day district. A year ago we took a reading of the district, and the total percentage was about 2.85 on the Ringelmann chart, and that included about 1,000 smoke stacks of all kinds. The loop district—that means strictly inside of the loop—was 2.35%. It is really phenomenal how low the percentage of smoke is in this district, when we realize the kind of plants there are in the downtown district. There are more obsolete, old, broken-down, Hartford settings, I believe, than in all the other districts,—six in all.

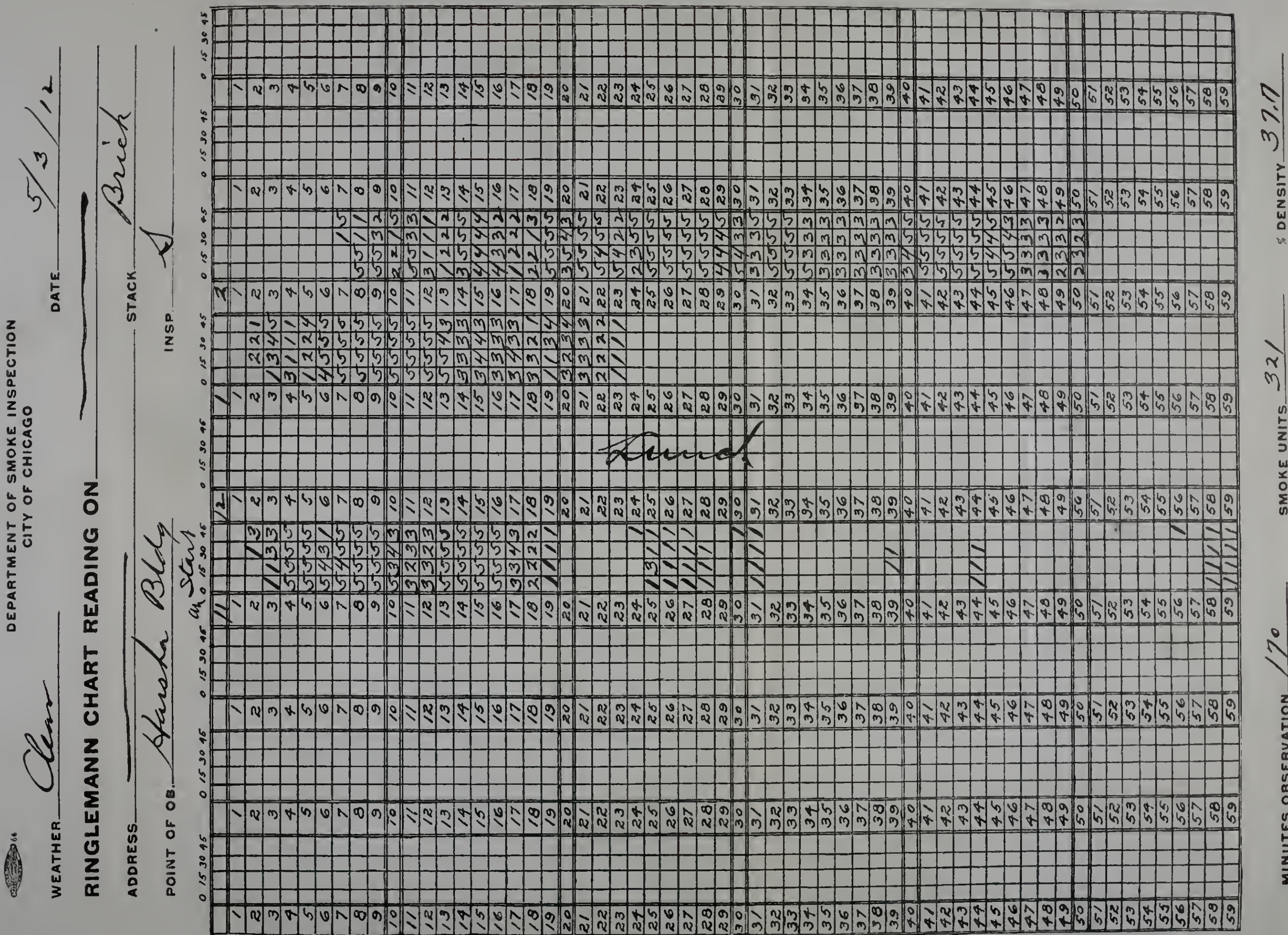
To illustrate: The First National Bank Building has made changes and has an up-to-date plant. In the next block is one of the most obsolete plants in the city. Yet the smoke density is about the same on the two. Of course, there is an element entering into that. In the obsolete plant extra care is given; the same is true of the First National Bank Building. That state of affairs extends all around town. The obsolete plant referred to is not burning semi-bituminous coal. These are problems which the Smoke Department is grappling with all the time. They are freaks, that is all.

Mr. Bement: The First National Bank Building has been mentioned. We have with with us Mr. W. L. Jackson, the Chief Engineer of that building. We would like to have him say something on that subject.

W. L. Jackson: I want to congratulate the Smoke Department of Chicago on what they have accomplished. I observe the conditions down town closely every day from the roof of our building, and every day is evidence of their good work. The problem of smoke prevention in Chicago is a very large one. Some people contend that it is the man behind the shovel who creates the smoke, but in plants where there is no shovel I do not see how the trouble can be remedied, and the chimneys do smoke, because there are settings right in the loop which are practically the same as all the up-to-date plants downtown, that smoke continually, and there is no coal shoveling.

In figuring the percentages of smoke, from the chart, we have a little different scheme. We have a smoke recorder and we endeavor, when we get densities of the different kinds of smoke on the smoke recorder and compare them with the smoke densities on the chart, to find out how they run. While I do not say that our plant does not smoke,—it does smoke a little now and then,—the difference in our smoke situation from the time that we took out the old stokers is a vast improvement. I think there has been no regret

WESTERN SOCIETY OF ENGINEERS.
Vol. XVII. No. 10. DEC., 1912
Monnett Smoke Problem.
Plate I.


DEPARTMENT OF SMOKE INSPECTION
CITY OF CHICAGO

RINGLEMANN CHART READING ON

WEATHER Clear DATE 5/3/12

ADDRESS STACK Brick

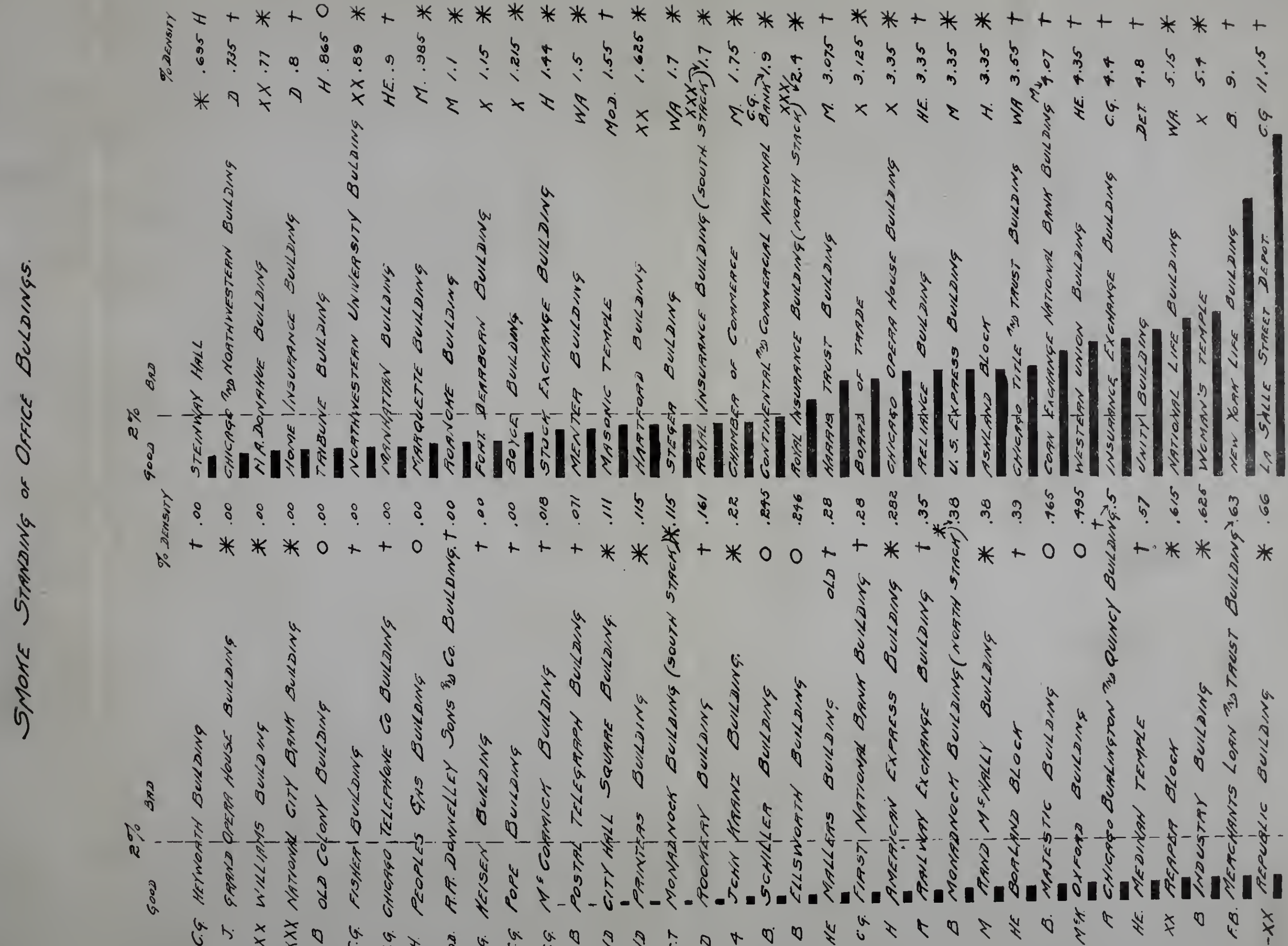
POINT OF OB. Harska Bldg INSP. S

at start

Lunch

MINUTES OBSERVATION 170 SMOKE UNITS 321 % DENSITY 37.7

WESTERN SOCIETY OF ENGINEERS.
Vol. XVII. No. 10. DEC., 1912
Monnett Smoke Problem.
Plate II.



for the amount of money that has been put into the change of stokers to obviate the smoke condition, as that was the primary thing that led up to the change.

A picture of an immense dredge, equipped with Jones stokers, was shown, and the assertion was made that it did not smoke. I want to take exception to that statement, because I have seen it smoke.

Another criticism I have to make is on the various percentages shown by several of the buildings around town. I have one building in mind that I look at every day, and on Plate II,—the tabulated sheet of office buildings,—it is shown that it is worse than the First National Bank Building. As a matter of fact, I have never observed the chimney of that building emitting smoke. How the tabulation was obtained I do not know. The construction of the plant is such that I do not believe it could be made to smoke under any condition, unless it was when there was a brand new green fire.

Once more I want to congratulate the employes of the Smoke Department; their efforts are producing splendid results.

Mr. Bement: Having in mind what Mr. Jackson has said and Mr. Pittsford's remarks, I will say that I do not think anybody in the room, with the exception of a few, has any conception whatever of the improvement that has taken place in this city as to smoke. Before the establishment of any kind of a smoke department, an inspector from the Department of Health—one man—was assigned, among other things, to look after smoke. (I do not remember now what year that was, but our transactions contain the record.) But previous to that time, 1880 to 1885, every Monday morning lights had to be used in the offices in most of the downtown buildings, because there was a cloud of smoke which hung over the city, making it dark until about noon time. About six years ago I said that about six times as much coal was burned in Chicago as in those earlier days, and made about one-eighth of the smoke that had been produced in those earlier days. Of course the ratio is now greater. It is impossible to get a clear idea of the enormous improvement that has taken place, and I do not think the situation is at all discouraging. I think the accomplishments have been remarkable. In fact, I know of one downtown chimney in those days that made more smoke in one hour than the whole downtown district does now in four days.

Henry Misostow: The first attack on smoke was made by an engineer who made tests with the intention of determining the most economical way of burning coal to increase steaming radius of steam boats. That was in England. Professor Fletcher, who lived at the same time as Professor Williams, decided that the most economical way to burn coal was to burn it without smoke.

Another point I would like to bring out is how these charts are made. One who does not follow the matter closely, cannot easily

see how the percentage can be 0.57 of 1%, when he measures just with a 20% standard. While Mr. Bird's point of reading from 1 to 100 is good, a man who is not acquainted with the system cannot conceive how those percentages are brought about. In making the Ringelmann chart, readings are taken every fifteen seconds and the number of the chart is put down. 1 means 20, 2 means 40, 3 means 60, and so on. Then whatever stack is clean, it goes as clean. Naturally during one hour we have four times 60; that makes 240 readings; and if you had two No. 1 and 239 readings of clean, in averaging up you get that fraction. I simply brought that out so that the man who is not posted on how the chart is made would not be confused.

Mr. Bement: I think I have discovered something about Mr. Monnett's paper which I am not sure he has realized. It is, that he is making smokelessness a fad, a fashion. It is a very good scheme, too, especially when the faulty ordinance under which he operates does not allow him to proceed against some of the people who are serious offenders. For example, a certain establishment at the end of one of his lists, is the worst one in the classification to which it belongs, but it does not violate the law. It makes smoke and it never stops, but never produces enough to violate the law. But that continual quantity accumulates into a very large quantity during the day, week, or year. The inspector cannot proceed against the offenders legally, but he can proceed against him in another way, which he does by showing him how bad he is compared with his neighbor. Generally, when we want people to do a certain thing, we create a fashion, and when we have done this, people wish to follow it, and are disappointed if they are not able to do so. Therefore, if we can make smokelessness fashionable, it will be very much better than anything else we can do.

C. W. Naylor, M. W. S. E.: There are a number of little things in connection with the Smoke Department which have not yet been arranged to suit me. One is that it takes forty-eight hours to get a notice to me from the Smoke Department. It goes to several of the officials of the building for which I am Chief Engineer, before it gets to me. I hope the Smoke Department will find some way of transmitting the information to the engineer soon after the fault.

The report upon the relative amount of smoke is a little confusing, although this is in no way a reflection on the integrity of the Smoke Department. Mr. Jackson expressed surprise to see one building which he thought made less smoke than the building for which he is engineer, lower down in the list. I am lower in the list than our wholesale department, yet they are getting smoke warnings all the time, while I get them only once in three or four months. Those are apparent inconsistencies in the readings. Of course I realize that it is impossible to make a report fit in all parts, because error will enter.

While it may not be germane to the subject, I have wondered why a device has not been found that will mechanically feed coal from the tender into the engine. It would not require a great deal of power.

I want to emphasize what Mr. Bement has said as to the clearness of the air now as compared with past years. It is unusual for an Illinois Central or Michigan Central engine, while in the Randolph Street yards, to emit a particle of smoke.

My father invented one of the first smoke burners, the old McGinnis type, and for two years I did little else than sit on the roof and watch smoke in what is now the loop district. There was no loop then. I fully agree with what Mr. Bement says. We made ten times as much smoke in the earlier days, burning only one-tenth as much coal, as we do now,—there is no question about it.

Mr. Jackson: One of the smoke inspectors a few moments ago mentioned an old, obsolete plant, where the smokeless conditions are as good as they are in an up-to-date one. I am thoroughly familiar with that plant, and it is about one-fifth the size of the First National and the American Trust plants combined; that building burns about five-eighths as much coal as we do, so that a smokeless stack does not necessarily indicate economy.

R. B. Drake: In general, with an ordinary horizontal water tube boiler, vertically baffled, is it possible, without a special furnace construction to get smokeless combustion with a reasonable excess of air; that is, keeping the CO_2 up above 6 or 8?

Mr. Monnett: In hand fired or stokers?

Mr. Drake: Stokers.

Mr. Jackson: That brings up the question as to what relation CO_2 has to economy. It is a well-known fact that there is one plant in this town which is turning out a kilowatt for about three mills, and the CO_2 never reaches above 4%.

Closure.

Mr. Monnett: I neglected to say, in the first place, that we have about 600 of these Ringelmann charts on file at the present time in the Smoke Department, being tabulated in different manners in which we find they will be valuable to classify for any class of equipment,—for instance, all Hartford settings, all chain grate plants, all Jones stoker plants, all hand-fired plants, and so forth. So that we have a lot of valuable data there to use as comparisons, enabling us to predict what result we may expect with different classes of equipment. That is one of the advantages that will accrue in tabulating this information.

In regard to preserving the code of the Chicago Smoke Department and the methods and equipment for different classes of service, different fuels, draft areas, smoke stacks, breaching areas, damper areas, and so forth, I will say that that material is being

collected at the present time with the idea of getting it into print. My experience with technical journals in the past four or five years has, in a way, fitted me to take up that part of the work. I feel that it is my duty to do it and it is being done. I felt that I ought to be in the position at least a year before attempting to do anything of this kind, and now that I have been here about fourteen or fifteen months I believe the time is ripe to begin. I hope that by next year the whole thing will be in printed form for use of consulting engineers, operating engineers, and anybody interested in designing new plants or the reconstruction of old plants.

Mr. Pittsford brought up the point that Mr. Jackson's modern chain-grate plant makes no better record than an old obsolete plant in the next block. The smoke game is full of freaks in this town. We find plants which we think ought not to smoke at all which do smoke occasionally; other plants which we think would naturally smoke all the time, smoke only once in a while. In reading the different stacks we will get a low reading on a certain stack one week and the next week we will get a higher reading. So that, as it is impossible to be watching any given stack all the time, we have to do the best we can in getting the information together. I do not know what plant Mr. Jackson alludes to when he says it is a better plant than his, because I consider his one of the best plants in the loop district.

Mr. Naylor brings up the proposition of feeding the coal from the tender into the engine. I will say, in this connection, that the Pennsylvania Railroad Co. is now and has been for the past year experimenting with an under-feed stoker in connection with locomotive service. It is a stoker which is a combination or modification of the Jones and Taylor stokers. It feeds in with retorts something like a Taylor stoker, and has a system of conveying the coal from a central hopper in the bottom of the tank, under the tank into the fire box of the engine. By the use of a steam cylinder, exactly the same amount of coal is forced into the fire by every stroke of the piston. The strokes of the piston are controlled by a throttle operated by the fireman sitting on the box; all he has to do is to sit on the box and operate this trottle and watch the steam and water. The engine is practically smokeless. It has been operating in Chicago for months. I have ridden on the engine myself, under all kinds of conditions,—heavy loads, switching, and every service to which an engine can be put in the city of Chicago,—and I never saw any No. 1 smoke issue from the stack. In Pittsburgh a great many experiments on this kind of engine have been made, and on the line to Pittsburgh probably a dozen engines of that character are being used. I believe the time will come when a locomotive having one of those stokers will be practically standard equipment. The only defect so far has been the freezing up of the coal in the winter time; and it seems almost

impossible to avoid that. The coal will get wet, the snow will melt and freeze again, and then the conveyor refuses to work. If that defect can be overcome, the stoker can be operated the year round.

With reference to the Jones stoker on the dredge, I will have to admit that a Jones stoker will smoke when cleaning fires if exceptional care is not used, and the marine firemen out there on that dredge on the lake probably do not take exceptional care during these periods,—not anywhere near the care taken with the ordinary Jones stoker plant where it is known that a stack is liable to be read any moment.

With regard to the possibility of making smokeless settings, with a horizontal water tube boiler, vertically passed,—that is one of the most difficult propositions with which we have to contend. A vertically passed water tube boiler is a natural smoker, and the only way to get a satisfactory setting is to insure excessive flame travel. We do set water tube boilers vertically baffled in Chicago, although there is an impression among consulting engineers that we will not pass that kind of setting. We will pass that kind of setting, for instance, on a chain grate if we have from 9 to 10 feet under the front header.

I know of a number of water tube boilers vertically passed that will be, in the near future, horizontally baffled. I know of one plant where $50,000 is being spent in putting in new chain grates, which have ten feet under the header, and I know a good many other plants that ought to be taken out, but it is not the fault of the stoker or the fault of the people running the stoker; it is the fault of the original setting. The settings were put in years ago when long-flame travel was not appreciated as it is today. For a hand-fired proposition I would say that it is practically an impossibility to put in a vertically passed, horizontal, water tube boiler and have it operate satisfactorily. I know of only one plant inside the city limits of Chicago running under those conditions, and that is a plant using a great deal of wood refuse and shavings and not a strictly coal-burning plant. I would not recommend such a plant and would hesitate a long time before I passed it. But we have many horizontally baffled water tube boilers, hand-fired with coal, and we can make them practically perfect. On Dearborn Street one is being operated which is as clean as any plant in the city of Chicago; it is hand-fired, running dirty screenings, and is saving $215.00 per month over another setting where it was necessary to burn No. 5 washed coal.

Mr. Bement: I would like to add just one remark to this discussion before we adjourn. I observe that there is a disposition to speak of a "horizontal baffling," when it would appear that reference is made to a tile furnace roof. I would suggest that when reference to the furnace is made, the term tile roof be employed. The baffling, correctly speaking, is the construction that directs the gases in their travel among the tubes.

December, 1912

PROCEEDINGS OF THE TWENTY-FIRST INTERNATIONAL IRRIGATION CONGRESS

Convened at Salt Lake City, Utah, Sept. 30th-Oct. 3rd, 1912.

The program attached herewith was, with the exception of a few omitted papers, followed practically as outlined.

Hereafter the proceedings of this Congress will be published as one number of the regular monthly bulletin issued, and the papers read before the Congress published in full. I have therefore arranged to have the Bulletin sent regularly to the society for the ensuing year and only a few of the points principally emphasized will be enumerated.

1. Loss of water by evaporation and percolation ranges from 10% to 60%, according to conditions. There is a multitude of such conditions and each case must be treated separately.

2. Bank and levee protection should be supplemented by the storage of flood waters above for irrigation and power purposes and at the same time feeding navigable waters.

3. About $70,000,000 obtained by sale of public lands has been used for reclamation; and this sum, supplemented by the water payments of settlers, would be sufficient to reclaim the arid lands capable of reclamation. When the lands have been reclaimed, the original capital could be devoted to other public works.

4. Thousands of Americans are treking to Canada, taking millions in capital with them. The Canadian homestead law is no more liberal than the American law, but the administering of the latter has been burdensome in the extreme to the homesteader, who, in a number of cases, has lost the fruits of his labor and found it almost impossible to secure patent. The new three-year homestead law has only lessened the burden. The remedy lies in better administering.

5. The Newlands river bill calls for an annual expenditure by the Government of $50,000,000 for ten years. Since railroad men point with calm anticipation to an expenditure of $5,000,000,000 in railroad extension during the coming five years, why could not one-tenth of that sum be expended by Congress in ten years?

6. Resolutions were introduced asking for federal inquiry into the practicability of establishing an irrigation land fund to assist settlers without means in securing farm homes.

7. Over 70% of the irrigation water supplied is wasted. More than 10% of the irrigated lands have become water logged.

8. There has been considerable agitation to crush "wild cat" land schemes, which schemes it is claimed are responsible for the failure of many irrigation projects, the ruin of many families, and the low prestige of irrigation securities among eastern capitalists.

9. Fourteen million acres of land have been reclaimed. Five hundred million acres remain to be reclaimed.

10. Irrigation is designed only to supplement the natural precipitation. When this has been done to the proper extent, the maximum advantage is obtained; when more moisture is added, the advantage becomes lost proportionately.

11. Transcontinental shipping will be lessened in cost 50% by the opening and use of the Panama Canal.

12. Good roads are very necessary in irrigated districts because of market conditions peculiar to such sections.

13. The only practical way to redeem water-logged and alkaline lands is by under-drainage, in accordance with systems applicable to such regions, not according to eastern practice.

14. Lands having as much as 1% to 5% slope are sometimes found to be water-logged, the water in some instances rising 40 or 50 feet and springing from the surface.

Over 1,000,000 acres of good farm land may be redeemed by underdrainage.

15. Considerable discussion ensued over the proposed merger of the irrigation and other national congresses.

REMARKS ON THE TOPICS.

1. From August 9th to 24th, 1887, the mean daily evaporation at Los Pinos Indian Reservation was 0.5537, of which 70% occurred between sunrise and sunset and the balance, 30%, during the night (U. S. Geographical Surveys West of 100th Meridian, Vol. 1).

(I have used the above as a standard in the design of water supply and irrigation works, as well as in experiments, and have found it quite satisfactory.

I have known losses from seepage to run as high as 50% in a few instances.)

2. By looking at the map of the United States, it will be seen that the sources of the great rivers west of the Mississippi Valley, are located in the Rocky Mountain regions. The Snake, Columbia, Colorado and Rio Grande rivers flow through western territory, and the Missouri, Mississippi, Platte, Arkansas, and Canadian rivers flow eastward, while those of the Great Basin have no outlet to the sea, but are lost on the deserts.

The Mississippi Valley alone could, if reclaimed by drainage, support 200,000,000 people; and the western territory by the aid of reclamation could support nearly half that many.

There are great possibilities ahead for the engineers in reclaiming this vast territory,—drainage and supplementary irrigation in humid and semi-humid sections, and irrigation and supplementary drainage in the arid sections.

The topography of the western portion of this great area would require an unusually large proportion of engineering work. The coast range of California and Oregon, and the large number of subordinate chains of the Great Basin and other portions of the elevated plateau, aggregate not less than 161 distinct ranges or mountain chains with a serrated axial profile of not less than 20 miles each in length. Utah alone has some 25 such ranges. An endless variety of conditions exist, peculiar to mountain waterways, intermittent streams, underground streams, floods, desert lakes, etc.

The Rocky Mountain water-shed is about 1,850 miles long.

4. Canada reports 73,320 American settlers as arriving during the past five months to October 1st, bringing with them $110,000,000 capital.

Canada reserves absolutely to the State all the mineral, timber, and power possibilities of the homesteads.

The subject of conflicting water right between power companies and irrigation projects appears to be prominent. For my part, I hardly see how this subject can ever cause any serious concern, because power concerns are water users, but in no sense do they consume the water.

GENERAL REMARKS.

Our engineers and promoters could find much to learn from the Italians in irrigation. Their works are unsurpassed from the engineer's as well as from the agriculturalist's viewpoint.

Our works have, in many instances, been designed according to the fancies and dictations of "wild-cat" promoters, involving large areas with insufficient water supply, resulting in the failure of the enterprises, ruin to poor families, and dishonest practices.

The agricultural possibilities of the entire territory, as well as the district at hand, should be understood. I think there is a deplorable lack of agricultural knowledge among a majority of us. The railroad engineer does

not obtain standing until he has become in part a railroad man. Similarly the engineer of an irrigation project should be what I will call the "agricultural engineer" and not the engineering agriculturalist. Agriculture can not be used to ornament an engineering enterprise, but rather the engineering is an agency in furthering the purposes of agriculture.

In Italy, transportation by highway, rail, and coast, irrigation and reclamation, have been intimately associated in placing that country on a firm modern agricultural basis, each one an equation in one common problem, and although pushed with great determination, there has been absolutely no "boom" character about either their works or their methods. The sociological condition of the kingdom has become changed entirely, its industrialism fostered, and its enterprises protected from the ravages of commercialism. Co-operation has been their watchword; success has been their reward.

The Irrigation Congress should be understood, not only by its members, but by its friends as well. It must be kept in mind from the start, that no matter how great its success may be, in the dissemination of knowledge among its members, its functions are purely political, its character agricultural. There need be no fears for the farming and engineering future; but in the direction of political success there is much to be done. The passage of acts on the part of Congress for the financial assistance of these great undertakings, their proper control for stability, the protection of the settlers, etc., involve many elements of wise and patriotic legislation. To do this, the education of the people at large is necessary, because Congress never leads public opinion. It responds only in proportion to the impressions made upon it by the voice of the people. In other words, the Irrigation Congress, together with the Dry Farming Congress, the Drainage Congress, and others face directly the principle of confederation, for however distinct and separately defined their various problems may be, their common cause is in reclaiming unused land. Their cause is common.

And it is because of this widespread political influence that could be brought to bear on Congress, by the organization and co-operation of these forces, that I advocate, not the merger, but the *association* of these forces of conquest. An experience both long and extensive in matters of organization confirms my belief in the plan advocated.

In a short address, I urged the Congress to discontinue their deliberation for and against a merger with other bodies, and suggested *association of national congresses*, with a view to centralizing and concentrating their political strength on any one objective at the proper time. But while the plan appeared to make a pronounced impression on many members, the remaining hours of the Congress were so short that the subject could not be taken into debate.

The program of the Congress was too crowded, with the result that the time limit for most of the papers read was only twenty minutes, while a few of the papers were dispensed with entirely. The subjects and essays, while excellent in themselves, were entirely too "heavy," for such short periods as well as the character of the assembly.

I believe much better results could be obtained if writers were urged to make their papers as simple and interesting as possible, and dispense with excessive quantities of comparative facts and figures. A few light, interesting articles would have the advantage of returning delegates to their homes with at least a few well-impressed, clear-cut ideas, rather than a large number of ideas hopelessly confused and ill at hand.

As stated at first, the various papers read will be published in the proceedings. Many of them are quite meritorious.

The personnel of the assembly impressed me as being exceptionally intelligent for one so large and widely recruited; their deliberations were characterized by good sense and proper parliamentary practice; their sessions were marked by deliberate conduct, wholesome unselfishness and

patriotic demeanor. They truly merit the hearty good will of all and the kindly co-operation of their fellow citizens.

October 12, 1912. GRANT ALLYN CAPRONI, Assoc. W. S. E.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, November 25, 1912.

An extra meeting of the Society (No. 801), the Electrical Section held jointly with the Chicago Section A. I. E. E., was held Monday evening, November 25th, 1912.

The meeting was called to order at 8:10 p. m. by Mr. G. T. Seely, with about 170 members and guests in attendance. The Secretary read the minutes of the last joint meeting held October 28th, which were approved. Mr. R. H. Rice, representing the American Institute of Electrical Engineers, read a communication from that Institute, pertaining to a change in the Constitution of that organization. Mr. Ernest Lunn, M. W. S. E., of the Commonwealth Edison Co., was asked to preside over the meeting. Mr. J. L. Woodbridge, chief engineer of the Electric Storage Battery Co., Philadelphia, was introduced, who read his paper on Economic Application of the Storage Battery. Mr. H. H. Smith, chief of research department, Edison Storage Battery Co., Orange, N. J., was then introduced, who read his paper on The Edison Storage Battery. Lantern slide illustrations of each of these papers were shown. Discussion followed from Ernest Lunn, P. B. Woodworth, G. H. Atkins, C. B. Frayer, R. F. Schuchardt, E. H. Freeman, D. Macrae, Carl Bessey, T. Milton, R. H. Rice, G. W. Cravens, A. Scheible, A. S. Dennison, G. M. Wilcox, with replies and closure from Messrs. Woodbridge and Smith.

Mr. Cravens offered a vote of thanks to these gentlemen for their contributions, which was carried.

Meeting adjourned about 10.20 p. m.

Regular Meeting, December 2, 1912.

A regular meeting of the Society (No. 802) was held Monday evening, December 2, 1912. The meeting was called to order at 8:25 p. m., with President Armstrong in the chair, and about 30 members and guests in attendance.

The Secretary read the minutes of the preceding regular meeting of November 4, 1912, which were approved.

The Secretary reported from the Board of Direction the following applications for membership:

Henry Misostow, Chicago.
John F. Brown, Chicago.
Earl K. Burton, St. Louis, Mo.
Frank X. Loeffler, Champaign, Ill.
Samuel P. Hendricks, Salt Lake City, Utah, transfer.
Fritz Balzer, Chicago, transfer.
Frank C. Huffman, Pekin, Ill.
Ira W. Dye, Culebra, C. Z.
Ralph A. Bennitt, Champaign, Ill.
Everett W. Turley, Chicago.
Bernard M. Lockard, Mason City, Ill.
Clarence M. Fuller, Champaign, Ill.
Thomas J. Irving, Springfield, Ill.

Clarence P. Griffith, Champaign, Ill.
Norman M. Stineman, Chicago, transfer.

Also that the following had been elected into membership:

Robert R. Caldwell, Beloit, Wis.	Associate Member
Fred J. Postel, Chicago	Member
C. S. Holcomb, Chicago, transferred from Junior to	Associate Member
Bernard Duchscher, Chicago	Member
Osborn Monnett, Chicago	Associate Member
Clarence A. Money, Chicago	Junior Member
Edward E. Reddersen, Champaign, Ill.	Student Member
Charles L. Samson, Harvey, Ill.	Member
Charles W. Kob, Chicago	Associate Member
Leonard B. Sairs, Chicago	Associate Member

The Secretary also reported that a canvass of the petitions for nominations for officers of the Society for 1913 showed the following nominations:

For President:
Albert Reichmann.

For First Vice-President:
A. Bement, Ernest McCullough, A. F. Robinson and G. T. Seely.

For Second Vice-President:
B. E. Grant, E. C. Shankland and I. L. Simmons.

For Third Vice-President:
John F. Hayford and M. B. Wells.

For Treasurer:
C. R. Dart, J. H. Prior and Albert Reichmann.

For Trustee (To serve 3 years):
F. E. Davidson, William Hoskins and Charles K. Mohler.

The chairman then introduced Mr. Richard T. Fox, of the Citizens' Street Cleaning Bureau, who read his paper on "Street Cleaning in Downtown Chicago." Discussion followed from Messrs. E. A. Rummler, H. S. Baker, Ernest McCullough, Albert Reichmann, W. W. DeBerard, H. P. Andresen, C. D. Hill, W. D. Gerber, the chairman, and with replies and a closure from Mr. Fox.

Meeting adjourned at 10 p. m.

Extra Meeting, December 9, 1912.

An extra meeting of the Society (No. 803) being that of the Bridge and Structural Section, was held Monday evening, December 9, 1912. The meeting was called to order at 8:25 p. m., Mr. I. F. Stern, Vice-chairman of the section, presiding, with about 75 members and guests in attendance.

The reading of the minutes was dispensed with. The chairman announced that at this meeting nominations were to be made for members of the Executive Committee of the Section for 1913, to be balloted for at the annual meeting of the Section in January, 1913. The following nominations were made:

For Chairman:
I. F. Stern.

For Vice-Chairman (one to elect):
Wm. Artingstall, J. H. Prior and A. F. Robinson.

For Director (two to elect):
E. A. Balsley, Lee Jutton and J. G. Kreer.

The chairman then introduced Prof. O. H. Basquin, who presented, in abstract, his paper on Columns, illustrating some points by the use of the blackboard.

Prof. H. F. Moore (University of Illinois) followed with his discussion of the subject, with two lantern slide illustrations. As the hour was

late, written discussions from Mr. John H. Griffith, Mr. H. R. Thayer and Mr. Lewis E. Moore, were postponed for an adjourned meeting to be held February 10, 1913.

Meeting adjourned at 10:15 p. m.

Extra Meeting, December 16, 1912.

An extra meeting of the Society (No. 804) was held Monday evening, December 16, 1912. The meeting was called to order about 8:25 p. m. by President Armstrong, who introduced Prof. F. R. Moulton, of the University of Chicago, who gave a valuable and entertaining illustrated lecture on "Other Worlds Than Ours."

The lecture was highly appreciated by a large audience of about 200 members and guests, including many ladies. A vote of thanks was returned to Prof. Moulton for his interesting lecture.

The meeting adjourned about 10:15 p. m.

Extra Meeting, December 23, 1912.

An extra meeting of the Society (No. 805), the Electrical Section, held jointly with the Chicago Section A. I. E. E. and the local members of the N. E. L. A., was held Monday evening, December 23, 1912, convening in Association Hall of the Y. M. C. A., 19 S. La Salle St., at 8 p. m., with about 300 in attendance.

Prof P. B. Woodworth presided. The reading of the minutes of the preceding meeting—November 25th—was dispensed with and the Secretary presented a petition with the necessary signatures for nominations of the Executive Committee of the Electrical Section for the year 1913, as follows:

For Chairman, to serve 1 year, R. F. Schuchardt.

For Vice-Chairman, to serve 1 year, F. J. Postel.

For member of committee to serve 3 years, P. B. Woodworth.

These are to be voted on at the next meeting of the Section.

Mr. W. L. Abbott was then introduced, who gave an account of the new Northwest Station of the Commonwealth Edison Company, with lantern slide illustrations. Some discussion of the subject was presented by Messrs. B. J. Arnold and G. T. Seely.

The Commonwealth Edison Orchestra was present and added materially to the entertainment of the evening.

Meeting adjourned soon after 10 p. m.

J. H. Warder,
Secretary.

BOOK REVIEWS.

The Books Reviewed Are in the Library of This Society.

Machine Design; Hoists, Derricks, Cranes. By H. D. Hess, M. E. J. B. Lippincott Co., Philadelphia. 1912. Cloth, 6 by 9 in.; pp. 368, including index. Price $5.00 net.

Primarily written for use in technical schools and colleges, the excellence of this book merits attention from all who are engaged in the general field of machine design.

The typography and make-up are unusually good, and the editing of the book seems to have been done with exceeding care. Minor items such as cross-indexing of subjects, uniform nomenclature, and liberal reference to antecedent or to supplementary reading matter, are noteworthy.

The aim of the author is not any novelty of subject matter or of treatment, but to present a reasonably complete summary of methods and data

for design or for criticism. For the latter purpose especially, the ready "accessibility" of subjects, and the orderly arrangement of all necessary data for any one subject complete in one chapter, recommend this volume to those who may have to exercise judgment in passing on designs, without having the advantage of specialized knowledge of crane design.

The first hundred pages, comprising Part 1, are devoted to materials and the elements of machine design, recording generally familiar formulas, tables and diagrams. The influence of German text-books shows clearly, although the matter has been thoroughly adjusted to American practice.

The sixty pages of Part 2, are devoted to the structural members and bracing of frames for hoists, jib cranes and overhead traveling crane girders. The treatment in such small compass is necessarily somewhat summary. However, on pages 108 to 112 is given an ingenious method of making allowance for lateral strength of members in flexure, presenting a diagram of curves for reduction of allowable fibre stress for beams under various conditions of loading, plotted to the ratio of span to radius of gyration of the compression flange, that will be found serviceable for designs in many forms of structure besides crane girders.

Part 3 treats of block, band, cone, disc and coil brakes and clutches; Part 4 of winches and hoists.

The next five chapters give, each complete in itself, a condensed yet thorough analysis of design and suitable detail of specifications for all the component parts of, respectively,—A Guyed Derrick, Post Jib and Wall Cranes and an Overhead Electric Traveling Crane.

Part 11 briefly outlines the calculation of the more important features of hoisting engines, and the twenty pages of Part 12 present very satisfactorily the subject of Locomotive Cranes.

Throughout the book the illustrative problems given are very clearly worked out, without any avoidable detail, and appear to have been selected with unusually good judgment. J. G. K.

Tables for Calculating Sizes of Steam Pipes for Low Pressure Heating. By Isaac Chaimovitsch, M. E. Domestic Engineering, Chicago. 1908. Cloth; 6½ by 4½ in.; pp. 47. Price $2.00. P. O. Box 298.

This little booklet will, undoubtedly, prove of value to heating engineers for proportioning pipe sizes. As stated by the author, and justly so, too many "rules of thumb" are generally used in proportioning pipe sizes of heating system. The basic formula from which the tables are calculated is well known and used in many text-books, and has been generally accepted as safe.

The calculated valves in the inserted tables should prove to be of assistance to the busy man who generally has not time enough to make careful calculations for the proper proportioning of steam supply piping. The style and manner in which the subject is treated is easily understood, and the application of the tables a simple matter, which adds to the merits of the book. R. G. R.

A Treatise on the Design and Construction of Roofs. By N. Clifford Ricker, B. S., M. Arch., D. Arch. John Wiley & Sons, New York, 1912. Cloth, 6 by 9 in.; pp. 419, including index. Price $5.00.

The preliminary estimate of a book must be based largely on the reputation of its author This book, then, must have a high standing, coming as it does from a man so widely and favorably known in the architectural profession.

The book is much more extended in scope than the author's earlier publication. He says in the preface: "No part of my 'Graphic Statics and Trussed Roofs' (published 1885) has been used in this volume."

The purpose of the book is well stated in its preface, as follows: "Fourteen years' experience with the state examinations for license to practise architecture in Illinois has clearly shown that applicants are usually able

to determine the stresses in the members of roof trusses, but are frequently unable to dimension them accordingly or to connect them properly at the apexes of the trusses. The necessary formulas and data are scattered in numerous reference works, and their selection and exact application require more time than is allowed to the busy architect or engineer.

"Therefore the purpose of the present work is to supply the data, methods, formulas, and tables required in the design of a roof, arranged in the simplest manner and so as to require the least time and labor in their application."

In scope the book is, in fact, a treatise on the subject of roofs. It begins with a chapter on Elements of Graphostatics, treating the subject briefly but very clearly; then comes a short chapter giving definitions of the terms relating to practical roof construction; and another giving weights of construction materials and the imposed loads. The next chapter treats of the stresses in trusses determined by graphical analysis, covering the subject very completely.

Stresses by the method of moments is treated briefly with the following comments: "The method was frequently employed before that of graphostatics became generally known to students and practitioners, and it is still very useful for checking the results obtained by the latter. But it requires more time and labor, and errors are not so readily detected."

A chapter of 37 pages is devoted to the lengths of members of roof trusses. This does not seem to be of much value, being little more than exercises in simple computations.

Then comes a chapter which deals with the supports for roofs, and particularly their stability under wind pressure. It considers the stresses in masonry walls, piers, footings and in steel framing.

The foregoing chapters comprise about one-half of the book and complete the theoretical portion of the work. The remainder of the book is devoted to the practice of design and construction, covering the strength of materials and formulas for their application to the various truss members; tables of strength of members; proportioning the members of the trusses; detailing connections; deformation of trusses due to shrinkage, temperature, etc.; computation of weight of trusses and their loads; and finally a complete study of a truss.

The scheme of treatment of the subject is to give a brief explanation of the principles involved and then illustrate them by numerous examples. Solutions of the problems are given complete. Quoting again from the preface, "Twenty-five examples of roofs are treated in successive chapters, each chapter being confined to a single stage in the process, such as determining stresses, dimensioning members and detailing connections, estimating weights of trusses, etc."

Thus Example No. 4 is a Fink truss with 16 panels. In Chapter IV is a complete graphical analysis of the stresses due to gravity and wind loads; in Chapter VII is the computation of the lengths of all of the members of the truss; in Chapter XI the dimensioning of truss members is illustrated for a number of the examples, but not for this particular case; Chapter XII works out the details of all of the connections; Chapter XIV illustrates the computation of weights for a number of examples, but does not include the one which we have selected for illustration.

The intervening chapters are devoted to the theoretical discussion and the preparation of data necessary for solving the examples.

The examples embrace simple triangular trusses; unsymmetrical trusses; segmental trusses; domes; cantilever trusses; three-hinged arches with and without the cantilevers; and hip roofs.

All tables of strength of materials and all formulas are in terms of tons. The preface states, "The author believes that the subject of the strength of materials may be placed in a far simpler form, more easily applicable to practical cases, by changing loads and safe coefficients of resistance from

pounds to tons, * * *" The writer does not agree with this, believing that the present tendency and the logical method is to use pounds rather than tons. The chapter devoted to the deformation of trusses concerns itself only with the resulting changes in shape of the structure and it gives no data regarding the stresses produced in adjacent members, such as walls and foundations, due to these deformations, nor does it give any data regarding stresses due to temperature changes.

An interesting portion of the book is Chapter V, which illustrates 70 typical forms of roof truss, together with the forms of their stressed diagrams. These illustrations cover every form of truss that is likely to be encountered in practice. The stress diagram given for this type will be of great help in laying out the diagram for the specific case under the type.

The book may not be of much value to men experienced in designing frame structures, but it will be of great value to students and to practitioners who are required to design roof framing only occasionally. With the aid of this book such designers can quickly refer to the particular type of truss they wish to design and by following the examples worked out in complete detail, can apply the methods to their own problem with a continuous check on the operations, thus insuring against the omission of any element or the wrong interpretation or application of any formula.

H. J. B.

FOWLER'S MECHANICAL ENGINEER'S POCKET BOOK, 1913. Edited by Wm. H. Fowler, Manchester, England. 15th Annual Edition. 4 by 6 in.; 585 pages. Illustrated. Many tables and formulæ; leather and gilt edges. Price, 2 shilling 6 pence. Scientific Publishing Company, Manchester, England.

Copies of earlier editions of this excellent and convenient hand book have been received and placed in the library of this Society; a copy of a new edition is none the less welcome. The book opens with a collection of tables, English and metrical, of weights and measures. A chapter on "Mensuration" follows with tables of areas, etc., of circles. Tables of squares and cubes and also logarithms, trigonometrical functions and reciprocals of numbers follow. Other tables of weights, etc., plates, bars, rods, wire, etc., are herein. The next section treats of Steam Boilers, material for, design and construction, types and performances, fittings and settings, followed by pages on fuels—utilization in practice—producer gas power, smoke prevention, etc. The next section gives consideration to the Steam Engine—in theory and in practice—strength of parts, superheating and condensers. Steam Turbines naturally follow, in design, construction, results obtained, tests, etc. Locomotives, design, construction, performance, etc., is of enough importance to begin a section by itself with tables of dimensions and weights. It is to be understood, of course, that the greater portion of the preceding relates to English practice, but it is of interest to American mechanical engineers. An interesting section is given to Engine Valves and Valve Gears, with diagrams of operations. Internal Combustion Engines receive due consideration with diagrams of operation, etc. This is an important matter and gas engines of one type or another are receiving the attention of many mechanical engineers. The succeeding section treats on the gases to be used in gas engines and results obtained. Naturally allied to these are internal combustion oil engines, design and results of operation. Pumps, centrifugal, reciprocating, and of other forms are duly considered. Other mechanical matters, as transmission of power by belts, ropes, gearing, hoisting machinery, mining machinery, springs, etc., receive due attention.

LIBRARY NOTES

MISCELLANEOUS GIFTS.

Buffalo Department of Public Works:
- Annual Reports, 1903, 1904, 1906, 1908, 1909, 1910, 1911. 7 volumes, paper.

Slason Thompson:
- The Railway Library, 1912. Cloth.

E. E. R. Tratman, M. W. S. E.:
- Journal, Cleveland Engineering Society, September, 1912. Pamphlet.
- Journal of Association of Engineering Societies, November, 1912. Pamphlet.
- Proceedings, Association of Transportation and Car Accounting Officers, June, 1912. Pam.
- Railway Signal Association, Advance Notice of Annual Convention. Pam.

American School of Correspondence:
- Alternating-Current Machinery, Wm. Esty. Cloth.

Scientific Publishing Co.:
- Fowler's Mechanical Engineer's Pocket Book, 1913. Leather.
- An Outline of the Metallurgy of Iron and Steel, Sexton & Primrose. Cloth.

McGraw-Hill Book Co.:
- Smoley's Parallel Tables of Logarithms and Squares. 7th ed. 1912. Leather.
- Engineering of Shops and Factories, H. G. Tyrrell. Cloth.

Domestic Engineering Co.:
- A Practical Manual of Steam and Hot Water Heating E. R. Pierce. Cloth.
- Notes on Heating and Ventilation, John R. Allen. Cloth.

Sanitary District of Chicago:
- Proceedings, 1911. Cloth.

GOVERNMENT PUBLICATIONS.

U. S. Geological Survey:
- Professional Papers, Nos. 69 and 74.
- Bulletins Nos. 498, 507, 508, 514, 515, 516, 517, 518, 519, 520, 523.
- Water Supply & Irrigation Papers, Nos. 284, 289, 290, 291, 294, 298, 304.

U. S. Bureau of Mines:
- Technical Papers, Nos. 25 and 28; Bulletins, Nos. 43 and 46.

Isthmian Canal Commission:
- Canal Record, Vol. V. Cloth.
- Annual Report, June 30, 1912. Paper.
- Census of Canal Zone, February 1, 1912. Pam.

U. S. Reclamation Service:
- Ninth and Tenth Annual Reports, 1909-10, 1910-11. Cloth.

EXCHANGES.

Canada Department of the Interior:
- Reports of Progress of Stream Measurements, 1909, 1910, Two pams.

Canada Commission of Conservation:
- Second Report, 1911; Third Report, 1912. Two vols., cloth.
- Sea Fisheries in Eastern Canada. Cloth.
- Land Fisheries, Minerals, 1911. Cloth.
- Water Powers of Canada, 1911. Cloth.
- Animal Sanctuaries in Labrador. Pam.

December, 1912

The Prevention of the Pollution of Canadian Surface Waters. Pam.
Illinois Highway Commission:
Modern Bridges for Illinois Highways. Pam.
Wayne County Commissioners, Detroit, Mich.:
Sixth Annual Report. Pam.
American Railway Master Mechanics' Association:
Proceedings, 1912. Cloth.
National Association of Cotton Manufacturers:
Transactions, 1912. Boards.
Chicago Harbor & Subway Commission:
Supplemental Report, October 30, 1912. Pam.
Southwestern Electrical and Gas Association:
Proceedings, 1910. Cloth.
New Orleans Sewerage and Water Board:
25th Semi-Annual Report, 1912. Pam.
Iowa Railroad Commission:
Annual Report, 1911. Cloth.
Philadelphia Academy of Natural Sciences:
Proceedings, Centenary Meeting, March, 1912. Folio.
South Dakota Society of Engineers and Surveyors:
Year Book and List of Members, 1912.

MEMBERSHIP

Additions:
Caldwell, Robert R., Beloit, Wis.......Associate Member
Duchscher, Bernard, Chicago.......Member
Holcomb, C. S., Chicago, transfer from Junior to.......Associate Member
Kob, Charles W., Chicago.......Associate Member
Money, Clarence A., Chicago.......Junior Member
Monnett, Osborn, Chicago.......Associate Member
Postel, Fred J., Chicago.......Member
Reddersen, Edward E., Champaign, Ill.......Student Member
Sairs, Leonard B., Chicago.......Associate Member
Samson, Charles L., Harvey, Ill.......Member

Deaths:
Bainbridge, F. H. ....December 3, 1912

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